Global Assessment of the SMAP Level-4 Soil Moisture Product Using Assimilation Diagnostics

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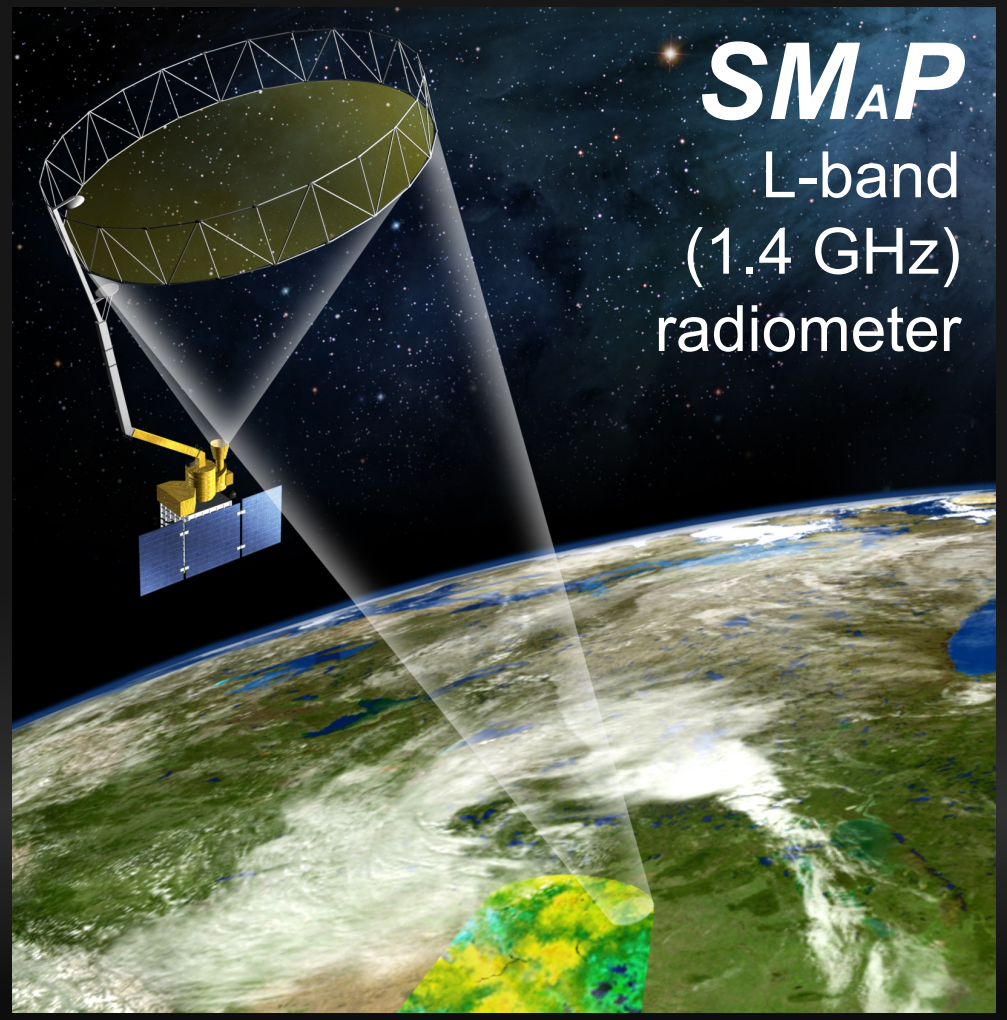
Wade Crow, John Kimball,
Randy Koster, and Joe Ardizzone

Motivation



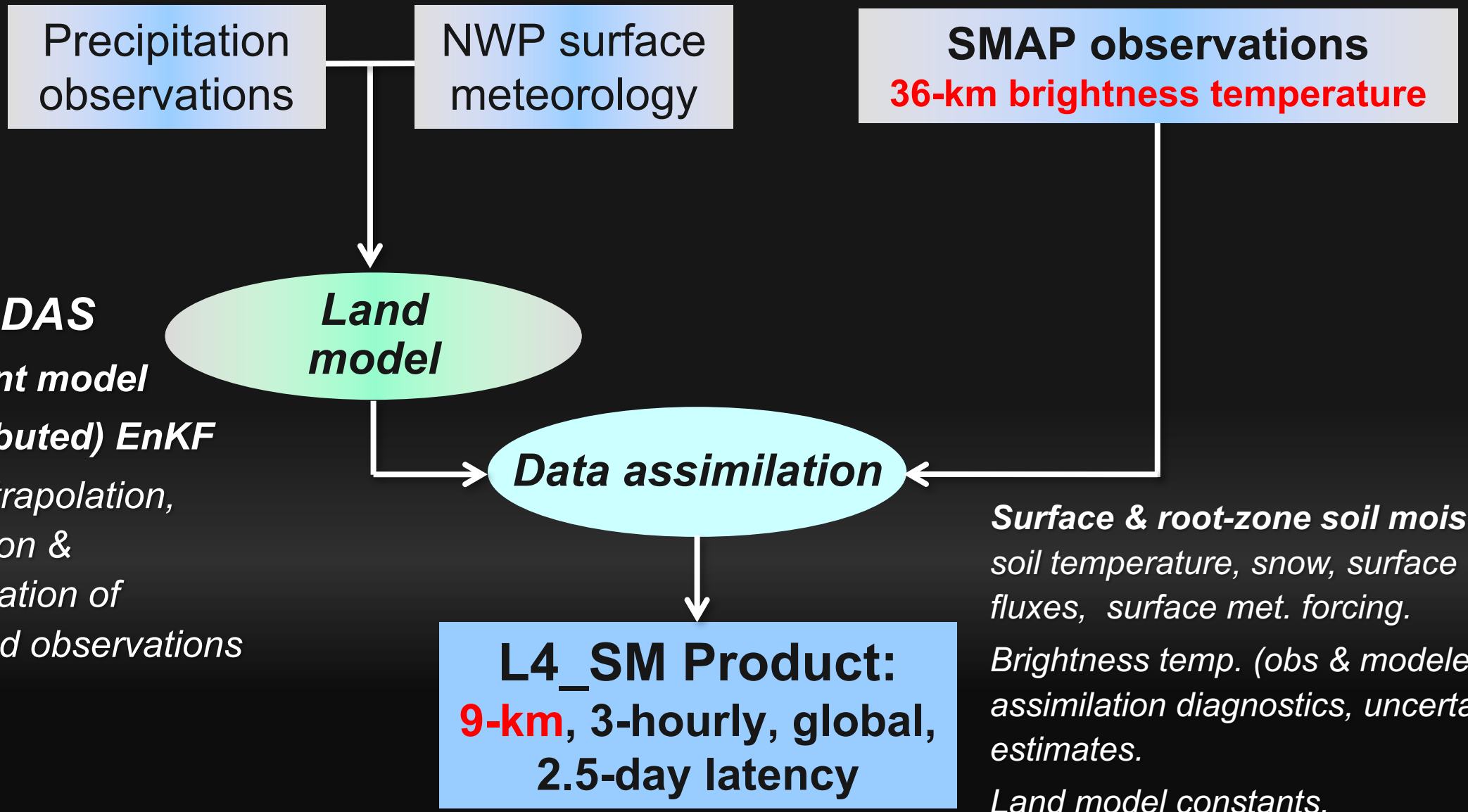
Sensitive only to **surface** soil moisture (~0-5 cm)

Key Objectives of the

Level 4 Soil Moisture (L4_SM) product:

1. **"Root-zone" soil moisture (0-100 cm)**
2. **Spatially & temporally complete**

Algorithm Overview



GEOS-5 LDAS

- ***Catchment model***
- ***3d (distributed) EnKF***

  spatial extrapolation, interpolation & disaggregation of assimilated observations

***Surface & root-zone soil moisture**, soil temperature, snow, surface fluxes, surface met. forcing.*

Brightness temp. (obs & modeled), assimilation diagnostics, uncertainty estimates.

Land model constants.

L4_SM Version 3

Data available publicly from NSIDC for 3/31/2015-present.

Used here (unless indicated otherwise): ***Version 3***
April 2015 – March 2017

New in Version 3:

Updated brightness temperature (Tb) scaling factors *based on:*

- *Newer & more SMOS Tbs where available (6 years of v6, rescaled to v5)*
- *SMAP Tbs elsewhere (2 years of Version 3)*
- *Model Tbs from updated "Nature Run" (NRv4.1)*

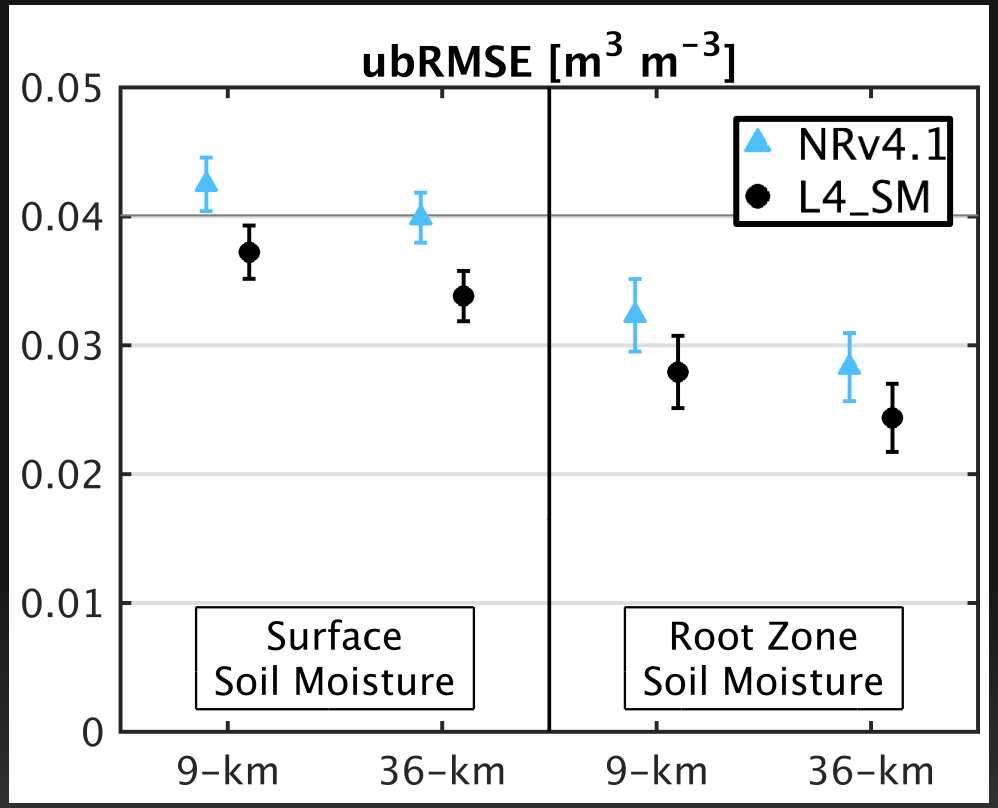
Retrospective forcing is better and more consistent w/ 2015-present data.

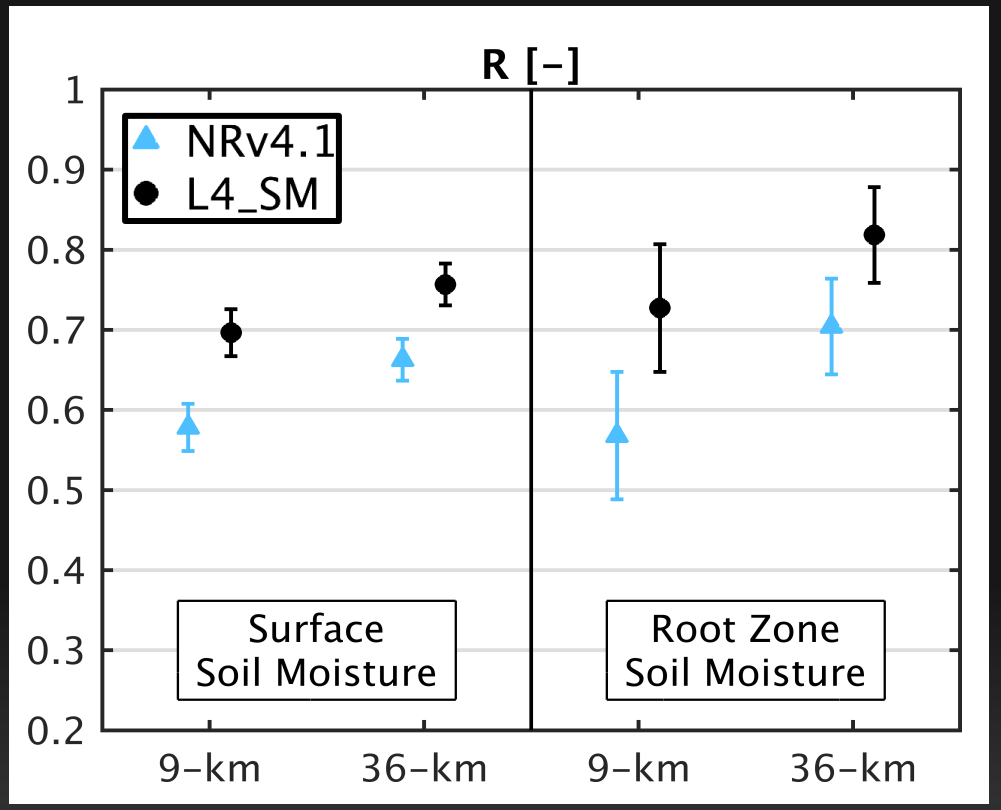
→ More SMAP observations assimilated.

Unchanged *Catchment model version & 2015-present forcing (w/ minimal exceptions).*

Objective was to avoid recalibration of L4_C algorithm.

Validation vs. Core Site In Situ Measurements





L4_SM shows small but consistent improvements over model-only data (NRv4.1).

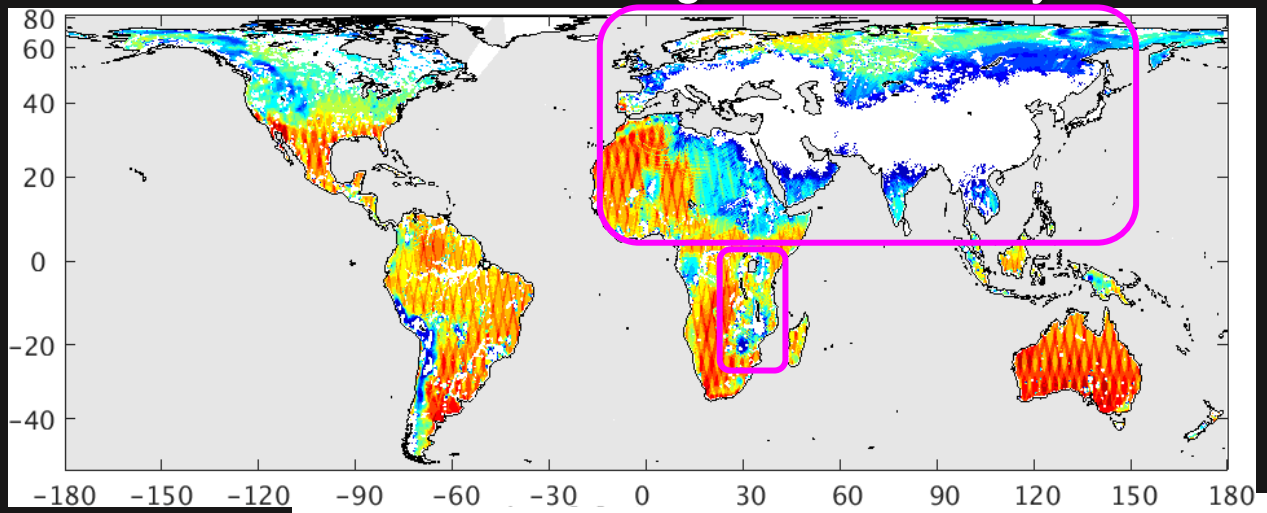
L4_SM meets ubRMSE accuracy requirement of 0.04 $m^3\ m^{-3}$.

Results nearly identical for Version 2 (Reichle et al. 2017; doi:10.1175/JHM-D-17-0063.1).

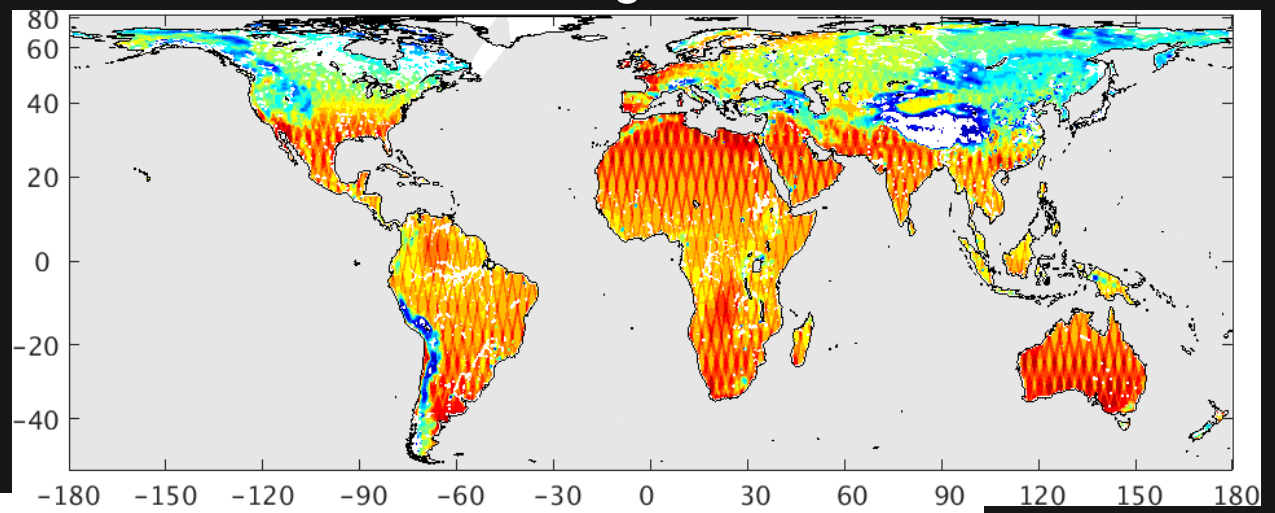
# Ref. Pixels	
SFSM 9 km	26
SFSM 36 km	17
RZSM 9 km	9
RZSM 36 km	7

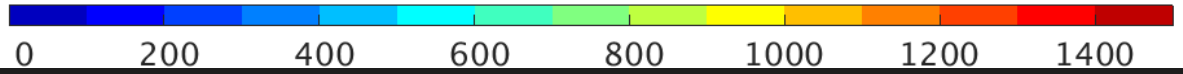
Number of Assimilated SMAP L1C_TB Observations

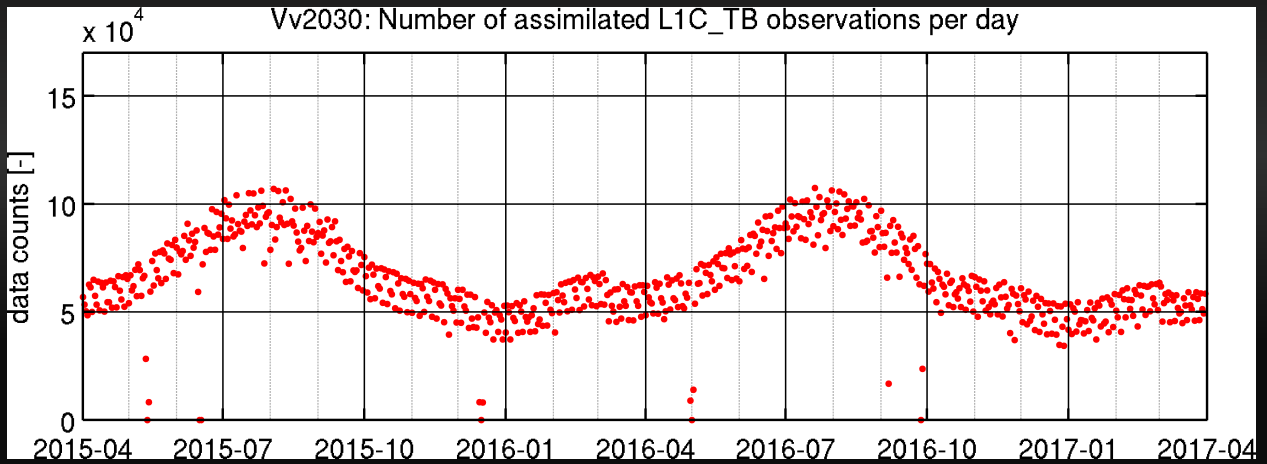
Version 2 – rescaling w/ SMOS only



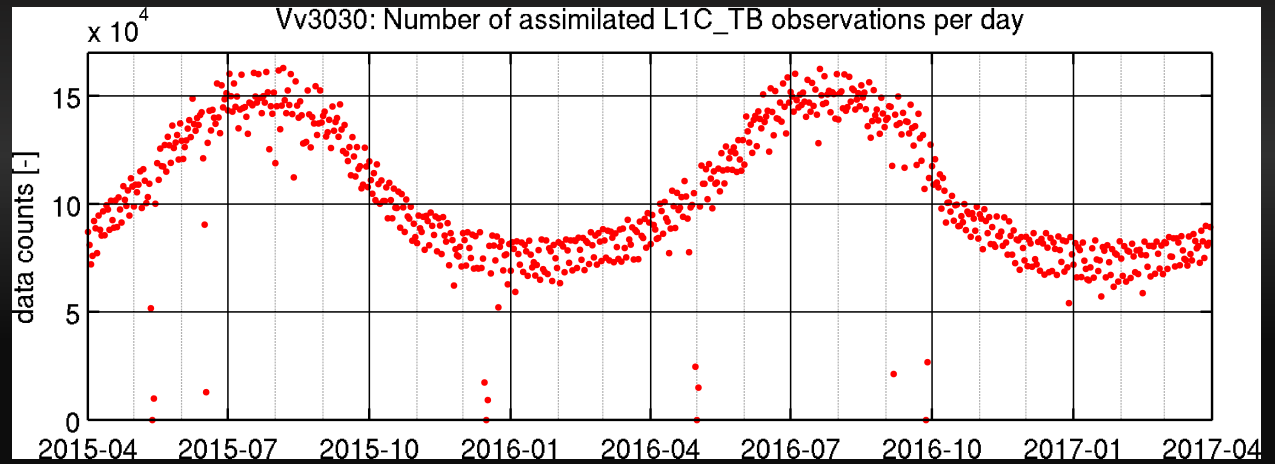
Version 3 – rescaling with SMOS & SMAP







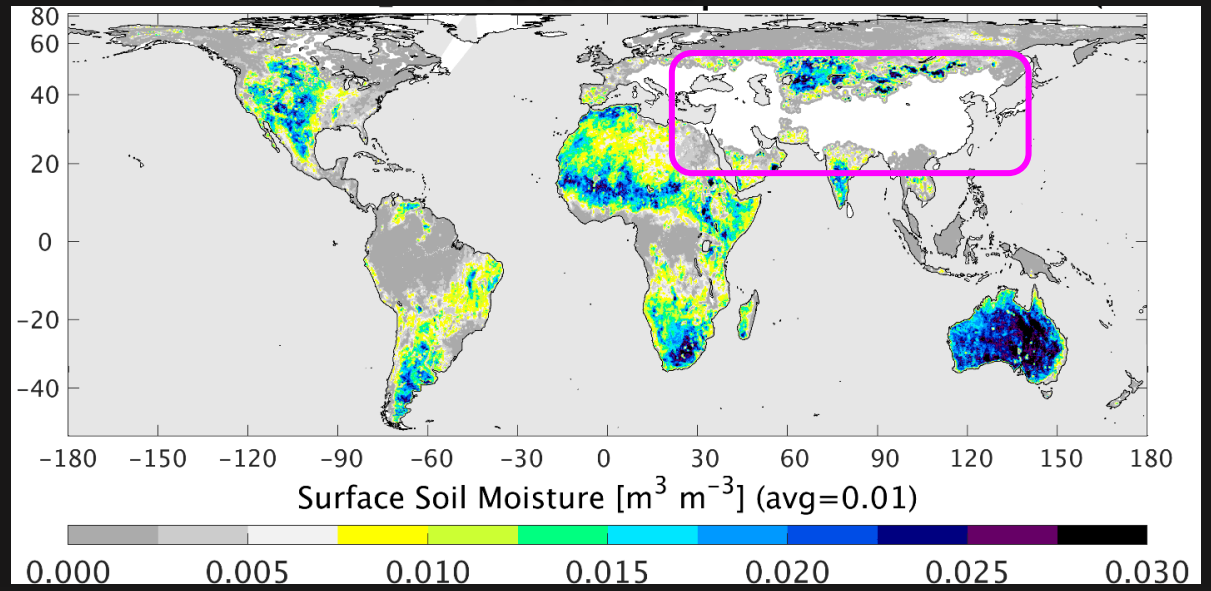
Average: 65,000 / day

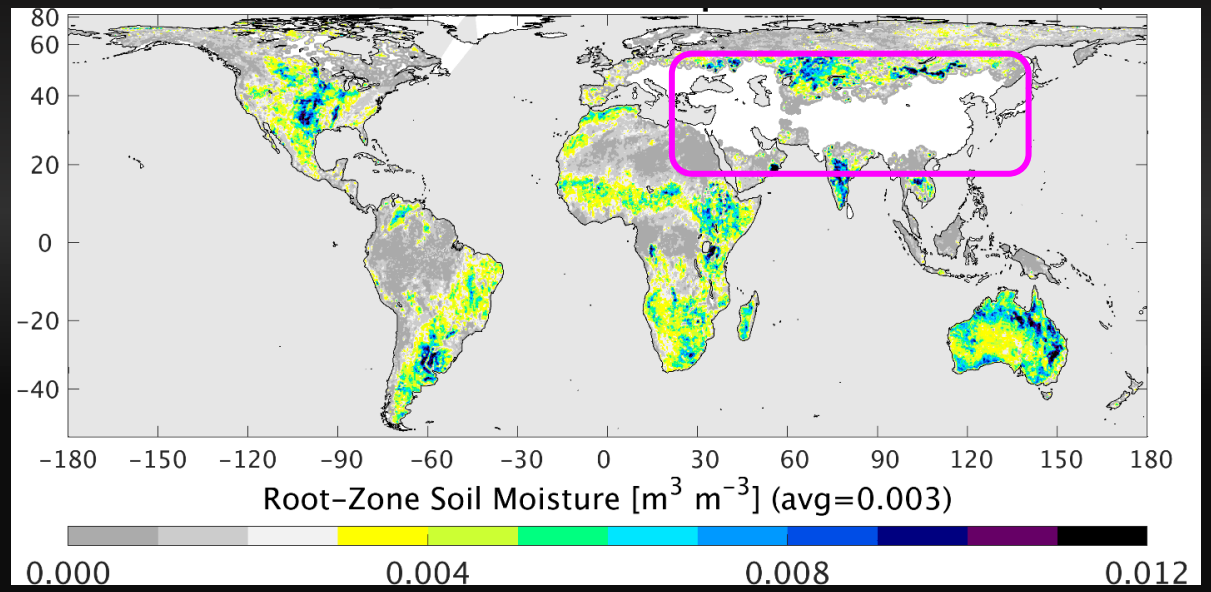


Average: **104,000** / day

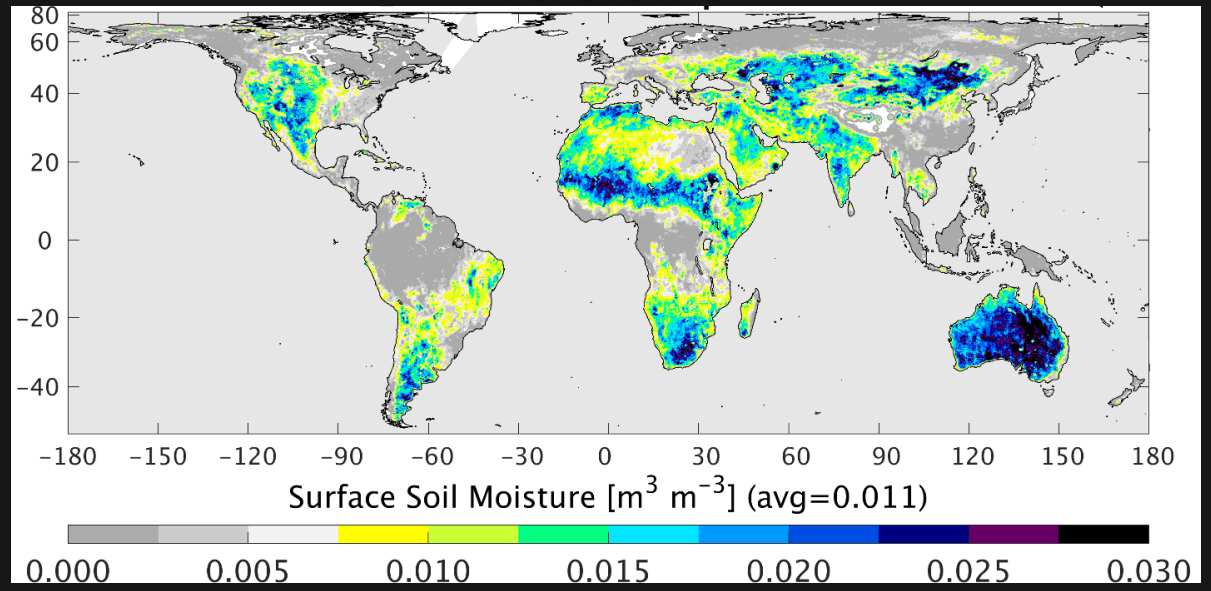
Std-dev Increments

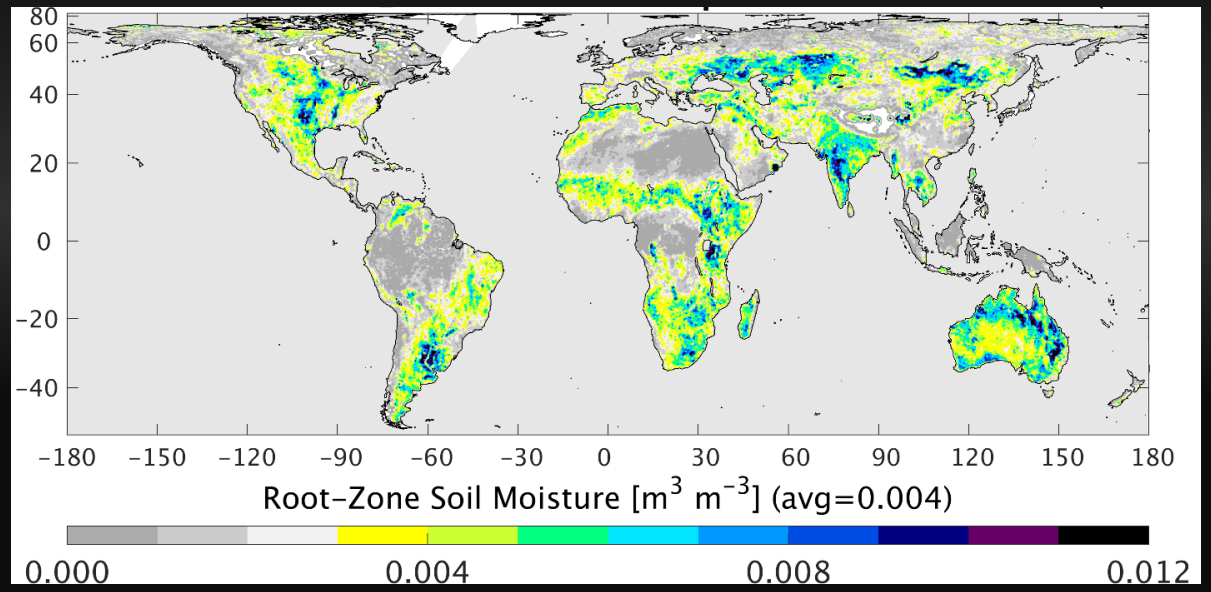
Version 2





Version 3

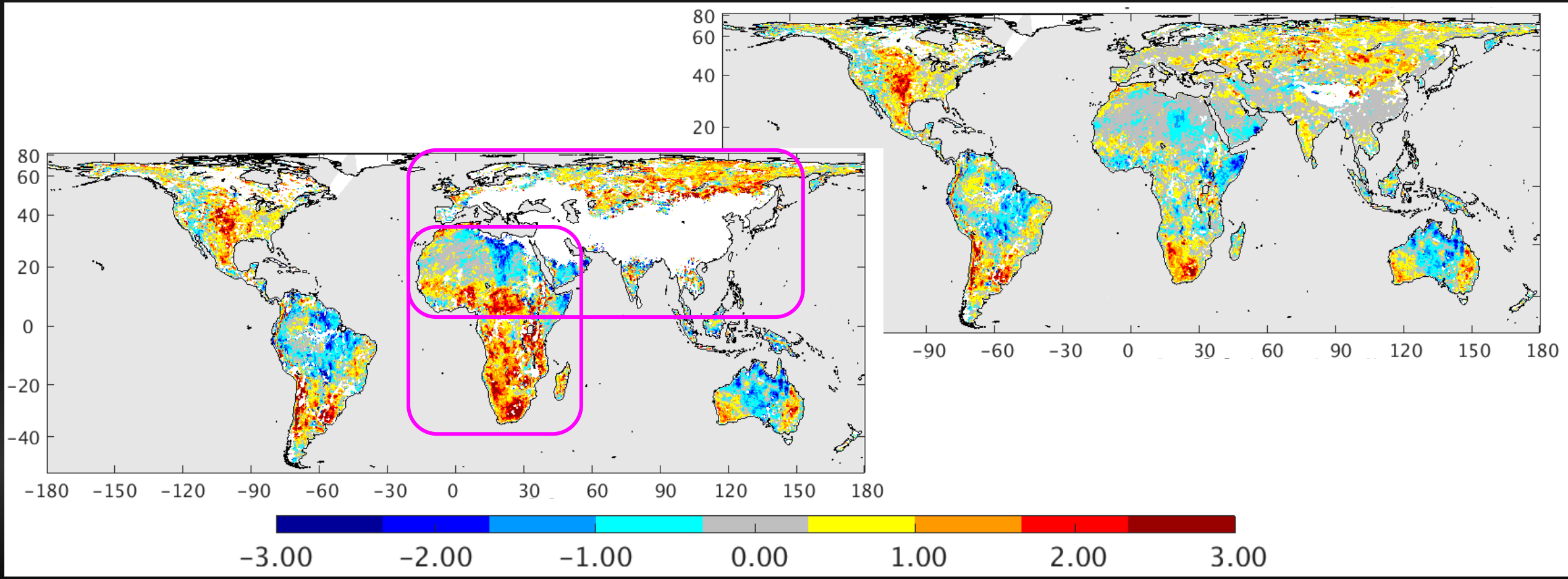




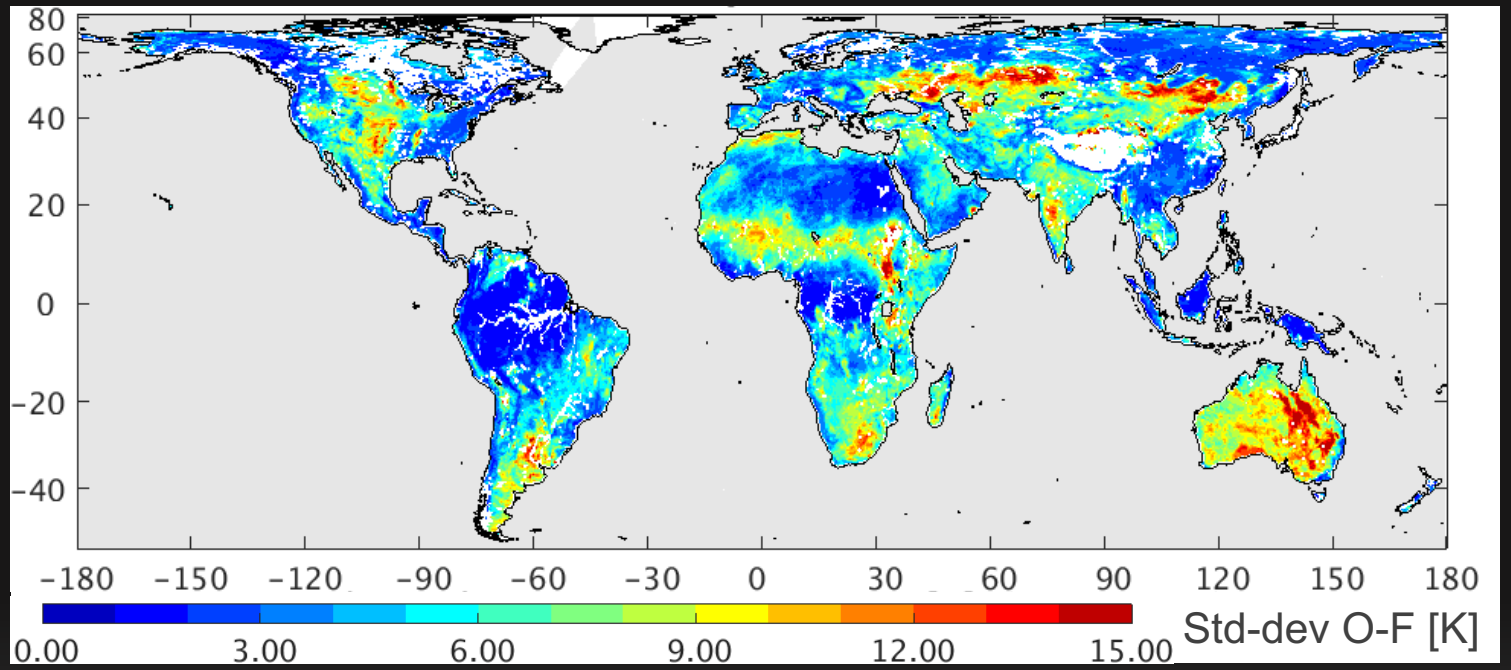
Mean O-F

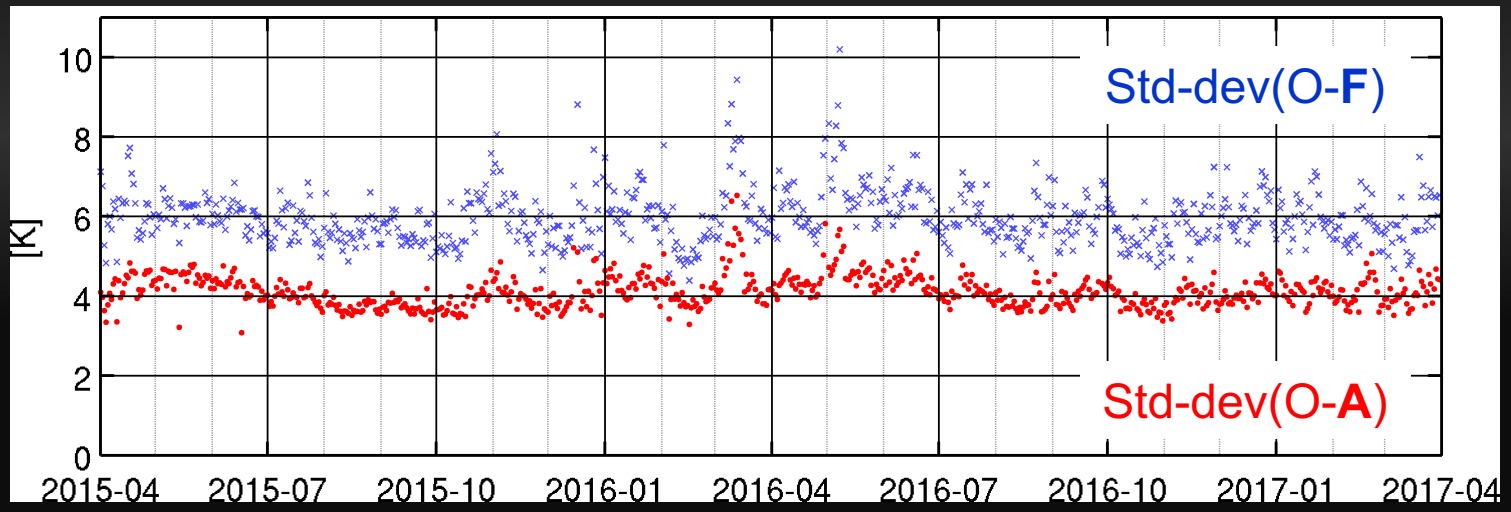
Version 2

Version 3



Std-dev O-F





Average:
O-F: 6 K
O-A: 4 K

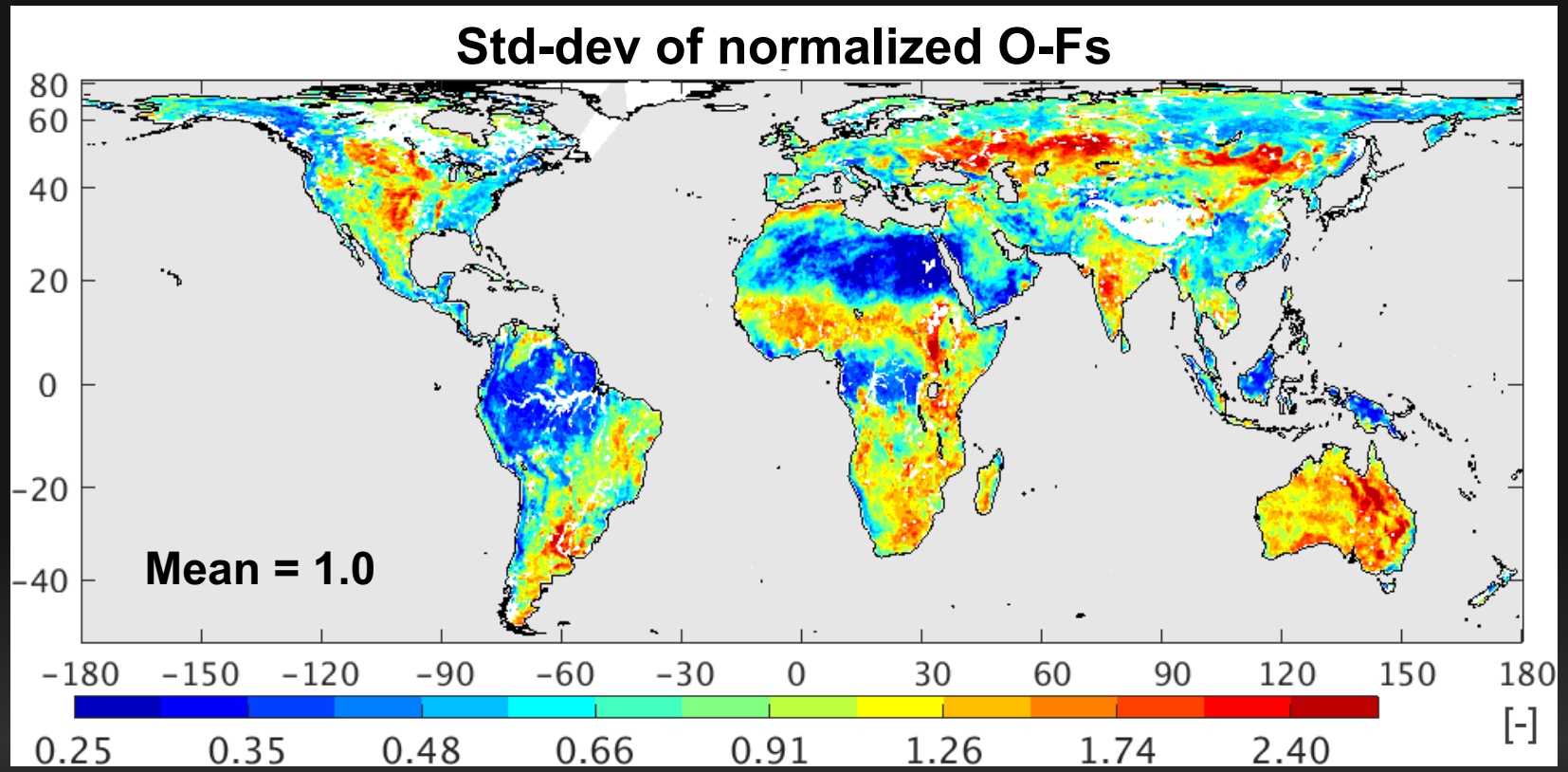
cf. Tb obs error
= 4 K

includes

instrument error
= 1.3 K
&
representative-
ness error
= 3.8 K

What is the quality of the uncertainty estimates?

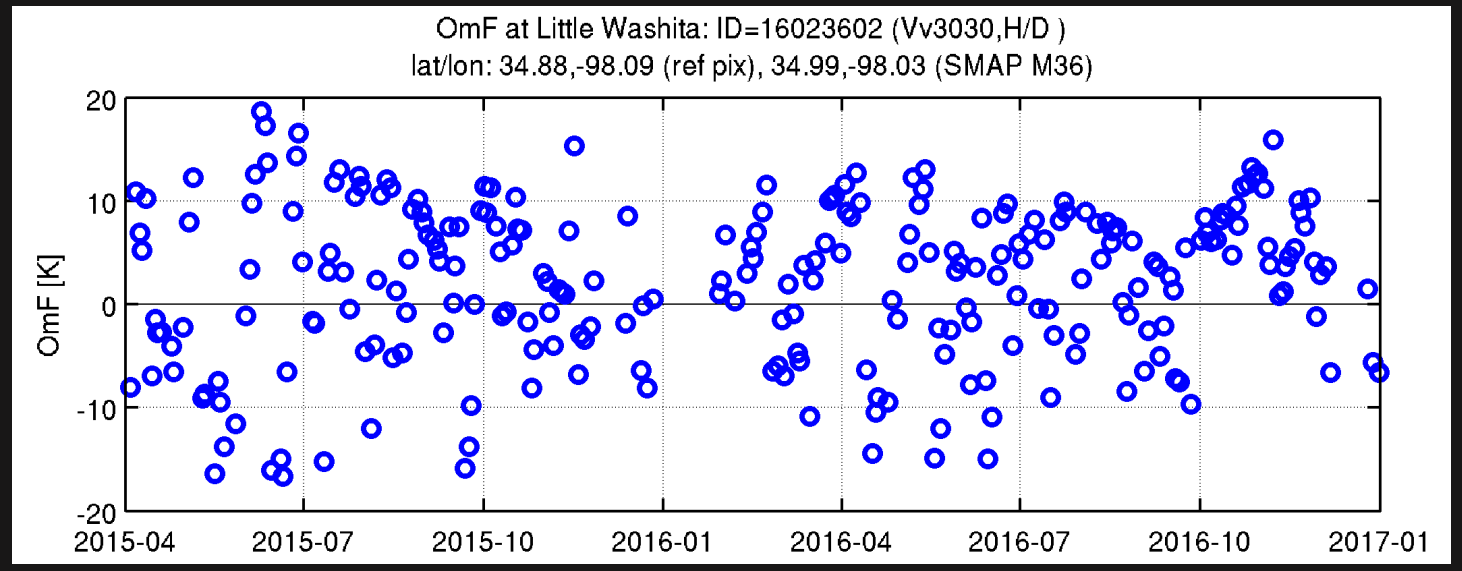
Normalize O-Fs with (assumed) error std-devs supplied to the analysis.



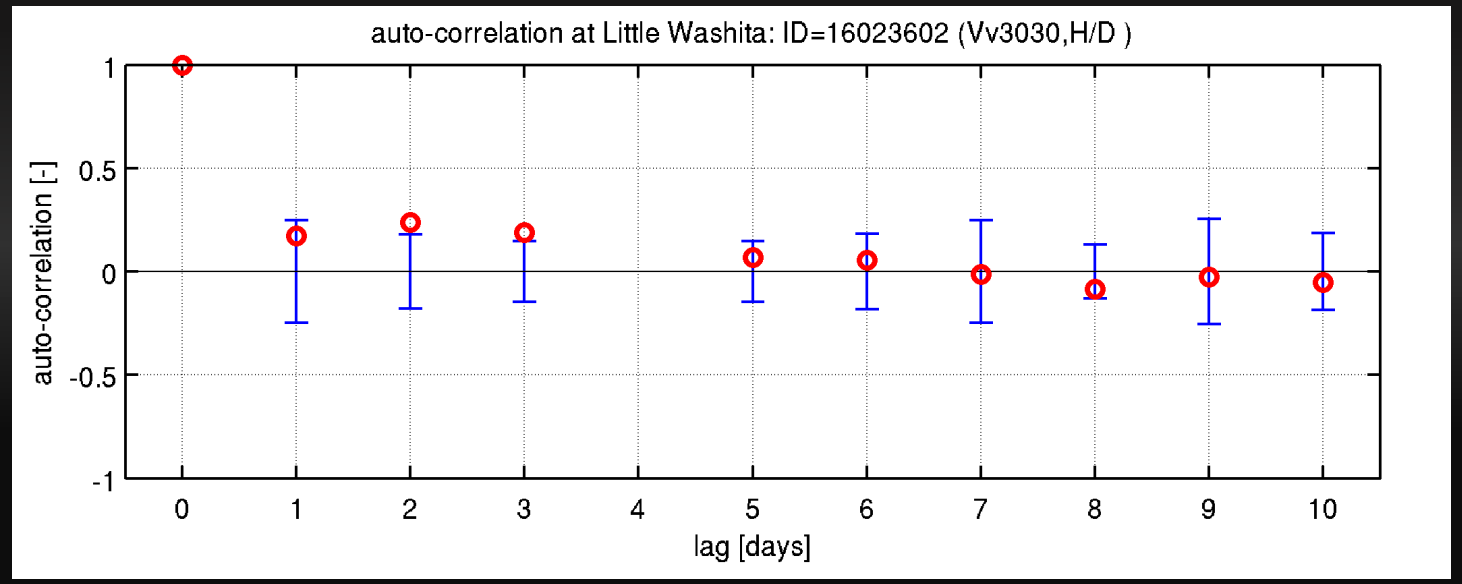
over-estimation **under-estimation**

of actual O-F errors

How efficiently do we use the observations?

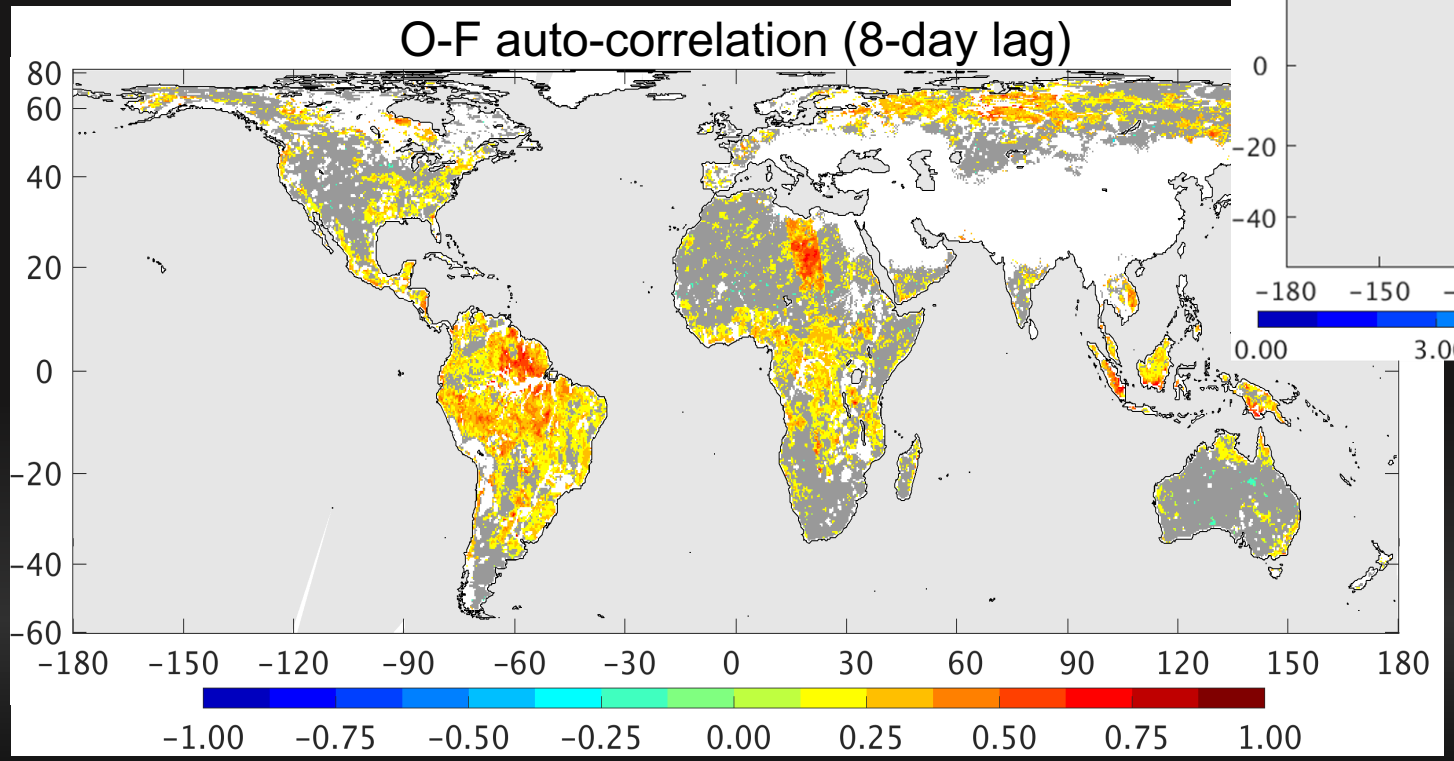


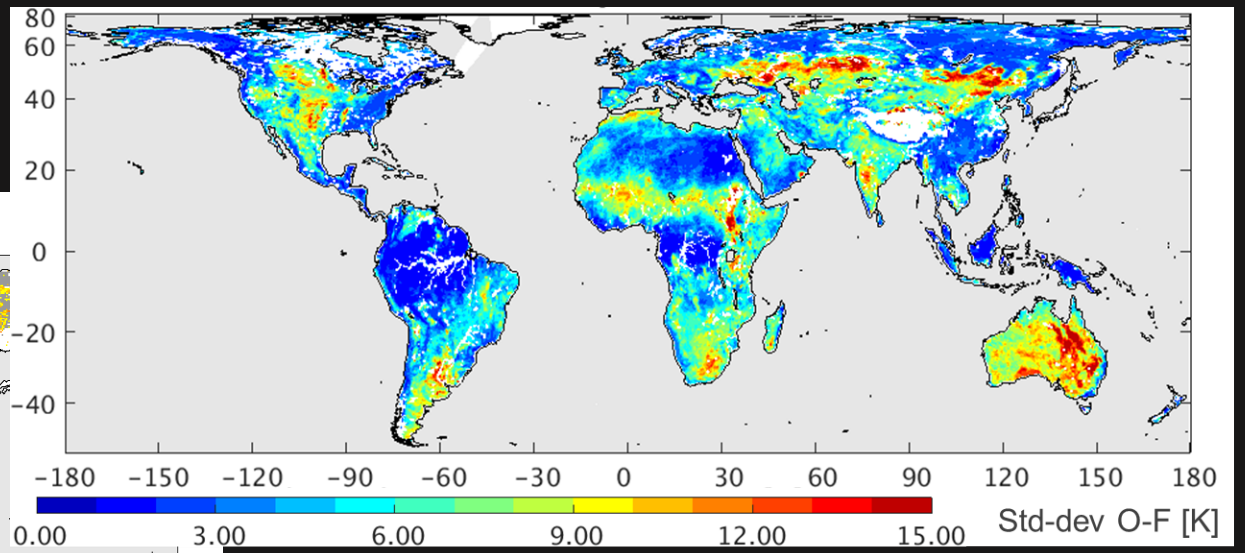
O-F time series at Little Washita, Oklahoma.



O-F auto-correlation measures “efficiency” of assimilation system.

How efficiently do we use the observations?



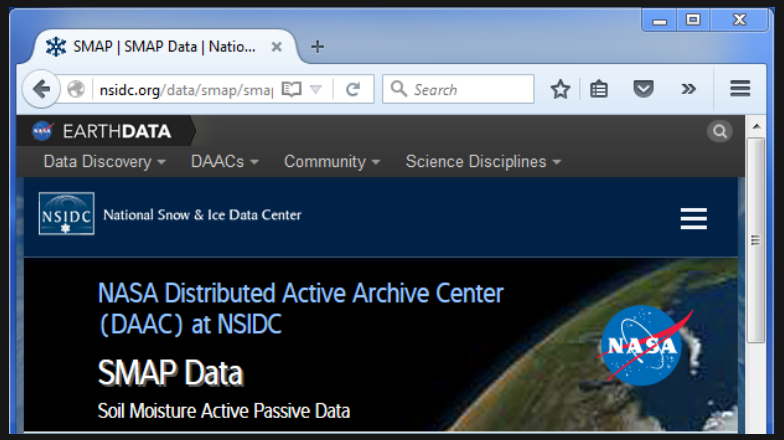


Observations *are* used efficiently where it matters.

Summary

- *The L4_SM algorithm assimilates SMAP brightness temperature (Tb) observations into the NASA Catchment model using a distributed (3d) EnKF.*
- *The L4_SM product provides global, 9-km, 3-hourly estimates with ~2.5-day latency.*
- *Version 3 of the L4_SM algorithm also assimilates SMAP Tbs in RFI-prone regions.*
- *The L4_SM analysis is largely unbiased, but there are modest regional biases in the O-F Tb residuals (<3 K).*
- *Typical instantaneous values are ~6 K for O-F Tb residuals and ~0.01 (~0.004) m^3 m^{-3} for surface (root-zone) soil moisture increments.*
- *Actual errors are over-estimated in deserts and densely vegetated regions and under-estimated in agricultural regions and wet-dry transition zones.*
- *SMAP observations are assimilated efficiently in western North America, the Sahel, and Australia, but not in many forested regions and the northern high latitudes.*

SMAP L4_SM Documentation



***Data Archive** & HTML Doc*

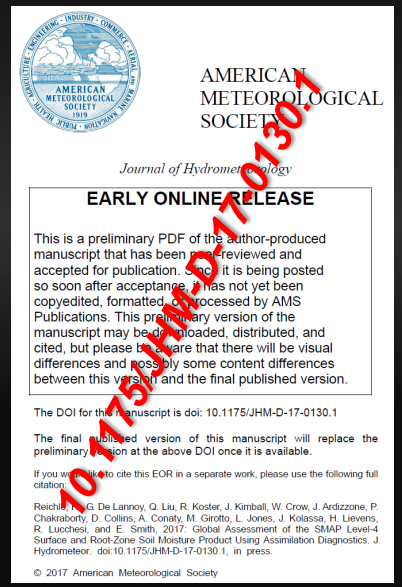
`http://nsidc.org/data/smap`

Product Specification Document

Algorithm Document

Data Assessment Reports

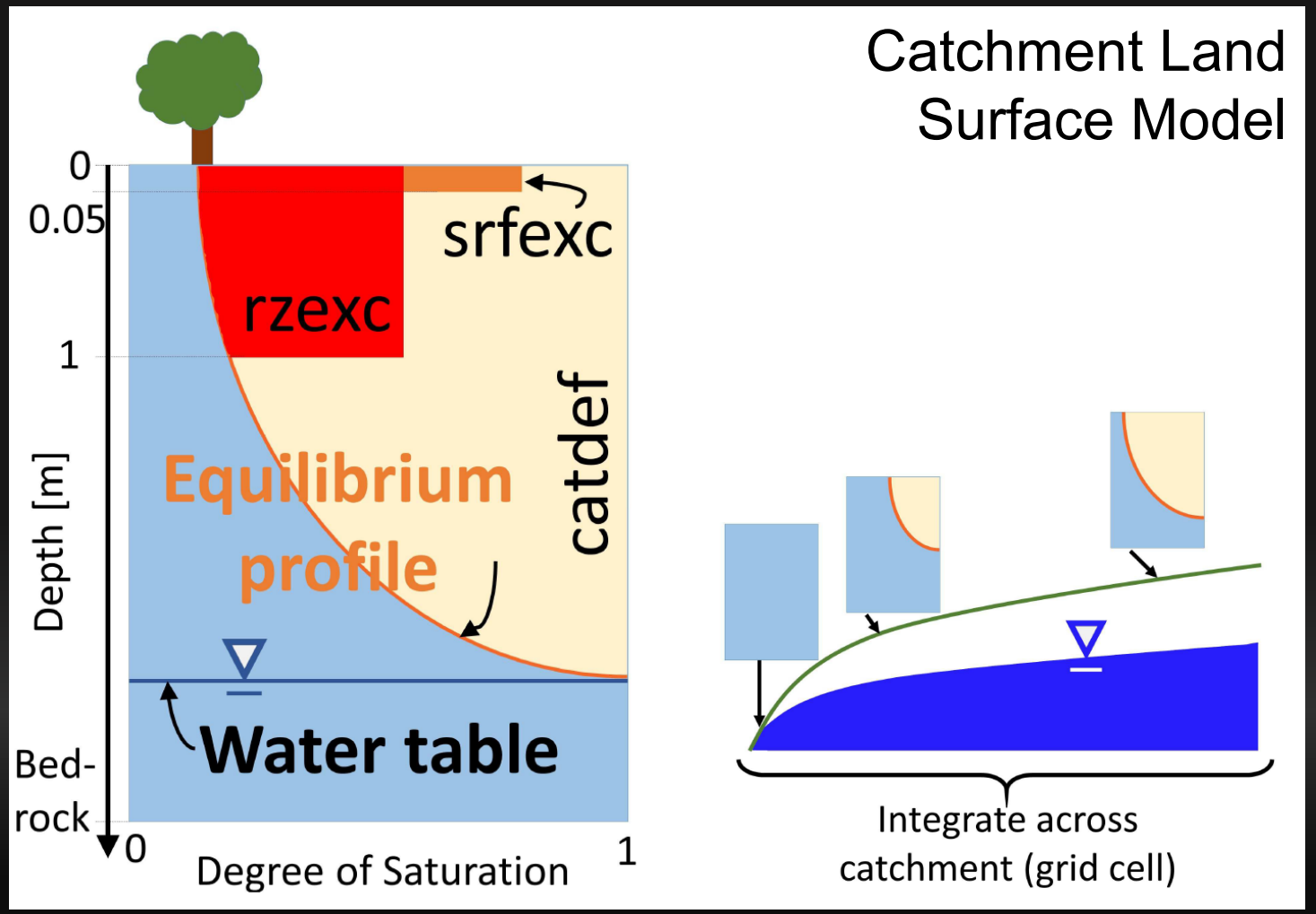
Peer-Reviewed Papers (J. Hydromet.)

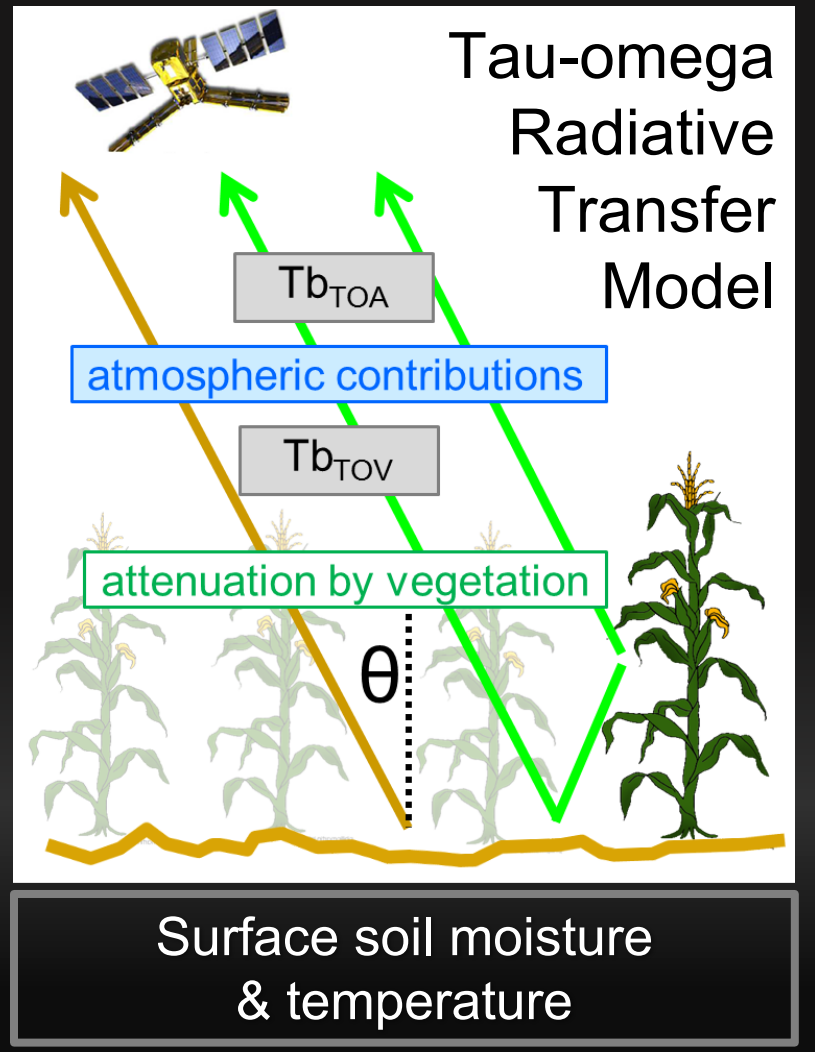


`http://gmao.gsfc.nasa.gov/GMAO_products/SMAP_L4`

EXTRA SLIDES

SMAP L4_SM modeling system



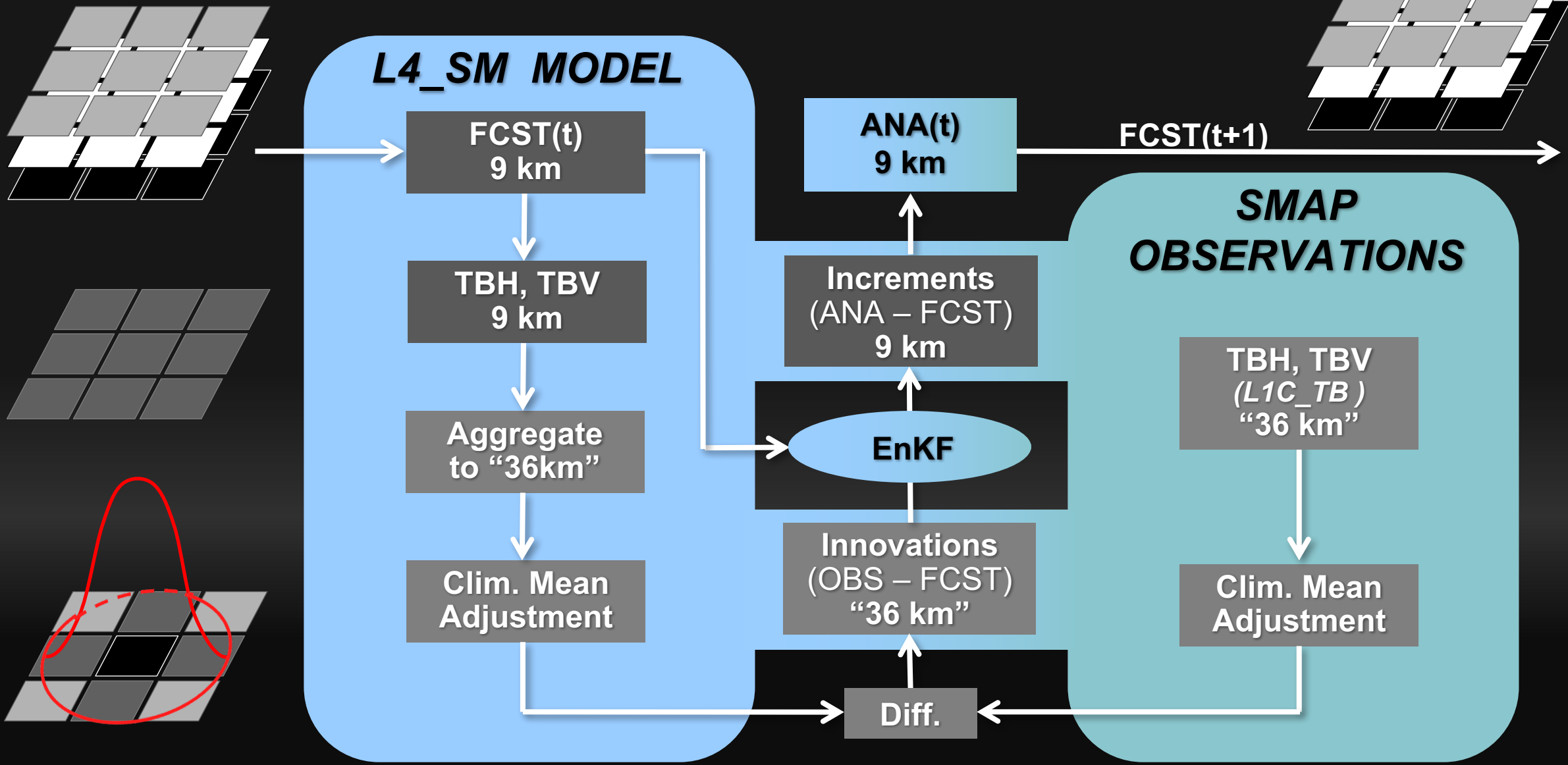


Surface soil moisture & temperature

Model estimates are **also subject to errors** (in model structure, parameters, and forcing).

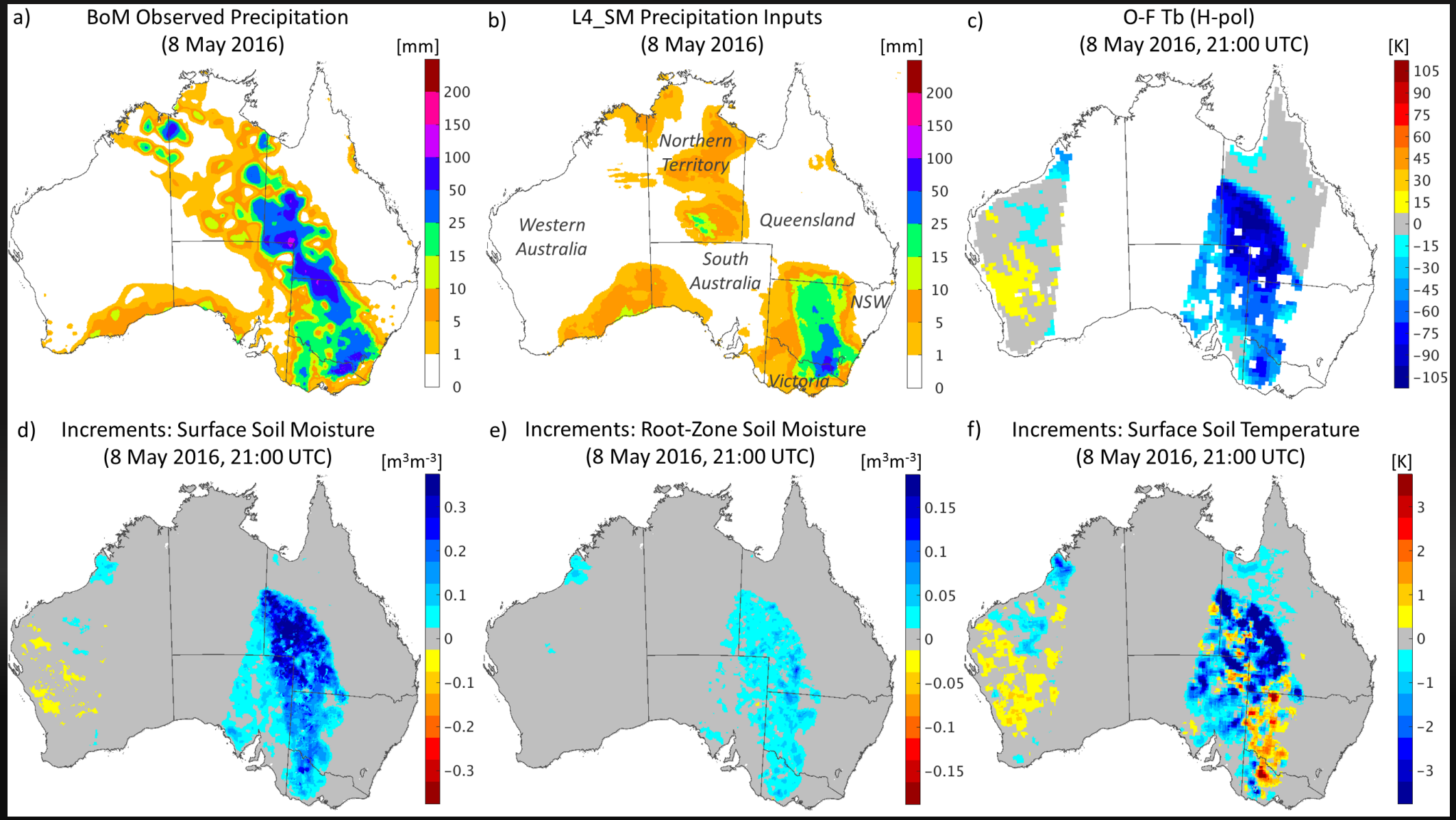
Koster et al. (2000), *JGR*, doi:10.1029/2000JD900327.
De Lannoy et al. (2013), *JHM*, doi:10.1175/JHM-D-12-092.1.

SMAP L4_SM soil moisture analysis



Reichle et al. (2017), *JHM*, doi:10.1175/JHM-D-17-0130.1.

SMAP L4_SM analysis – 2100 UTC 8 May 2016



Reichle et al. (2017), *JHM*, doi:10.1175/JHM-D-17-0130.1.

L4_SM Version 3 – Model Changes

*Catchment model & forcing for 2015-present **unchanged**, except:*

- *Albedo no longer inferred from net shortwave forcing.*

  (Matters only if snow cover differs between NR and GEOS-5 NWP system providing forcing.)

- *Late-look CPCU precipitation data (minor impact).*

→ Expect ~identical climatology for Version 2 and 3 during SMAP period.

(Objective was to avoid recalibration of L4_C algorithm.)

Updated model-only simulation (NRv4.1):

- *GEOS-**5.12** RP/FP-IT forcing (2000-2014)*

  (NRv4 used GEOS-5.9 RP/FP-IT forcing.)

→ Better matches GEOS-5 FP forcing during SMAP ops period.

Updated soil moisture climatology based on 16-years of NRv4.1:

→ Expect better soil moisture percentile output.

L4_SM Version 3 – Analysis Changes

Updated brightness temperature scaling factors based on:

- *6 years of SMOS v6 (rescaled to SMOS v5) where available*
- *2 years of SMAP Version 3 elsewhere*
- *Model Tbs from ensemble version of NRv4.1*

→ More SMAP observations assimilated.

Used R14 L1C_TB through 24 Apr 2017.

Screened out bad L1 Tb half-orbits (e.g., granules w/ atmospheric correction bug).

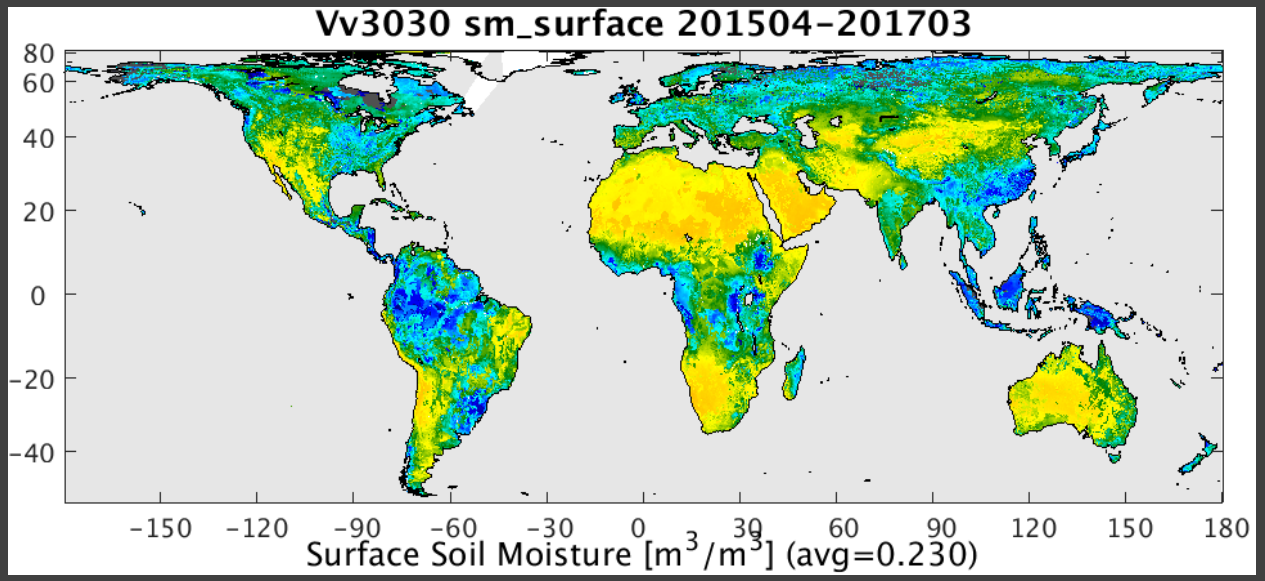
(Reprocessed & corrected R15 L1 Tb half-orbits were not available in time.)

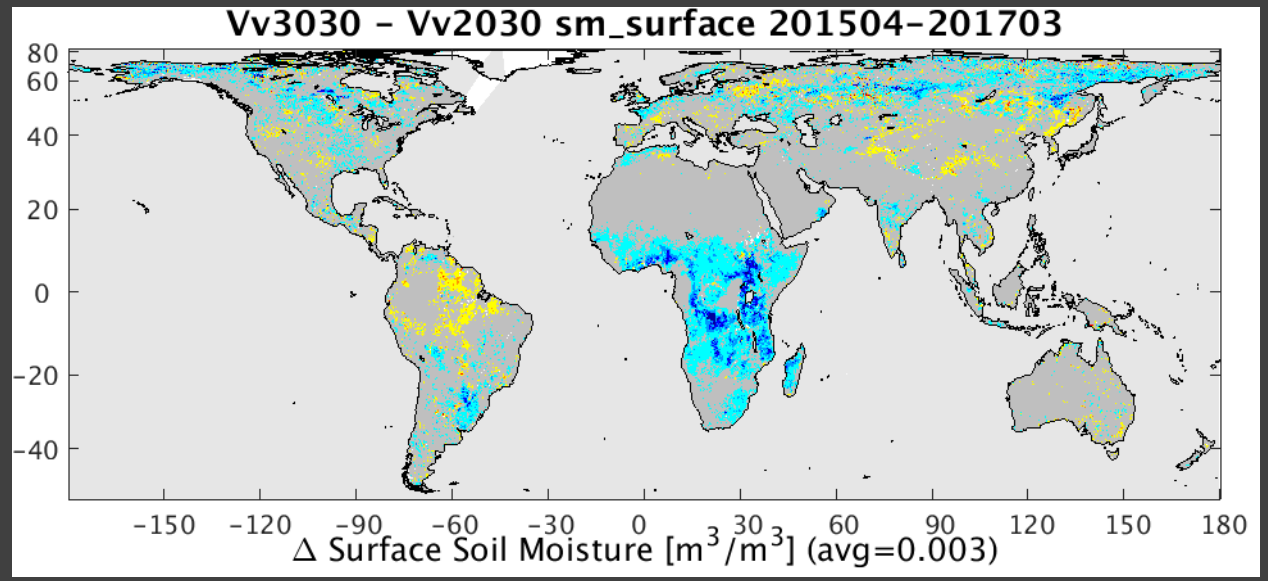
(L4_SM Version 2 used R13 through 6 Dec 2016.)

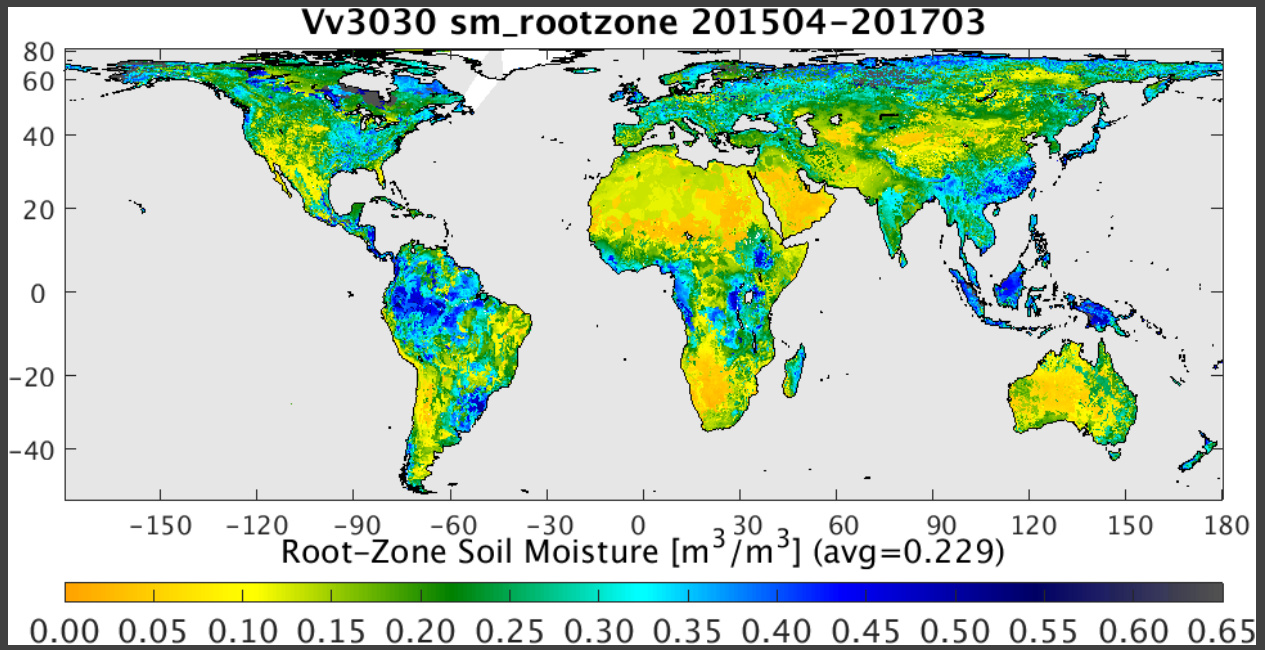
→ Minor clean-up.

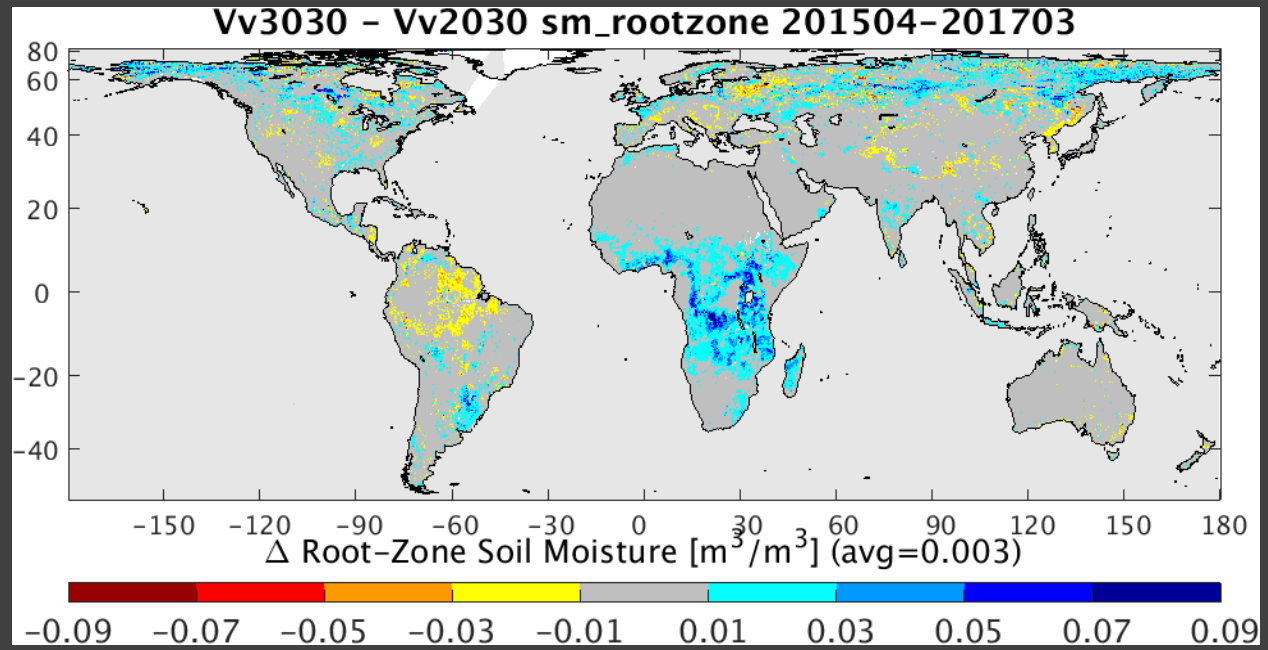
GMAO

Soil Moisture Climatology









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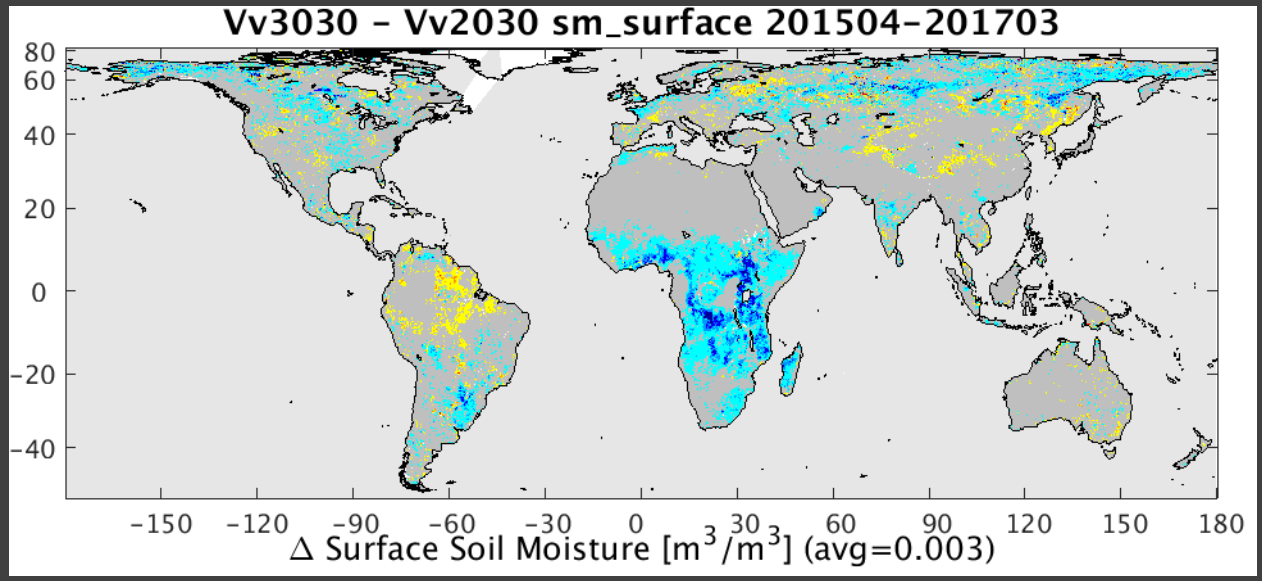
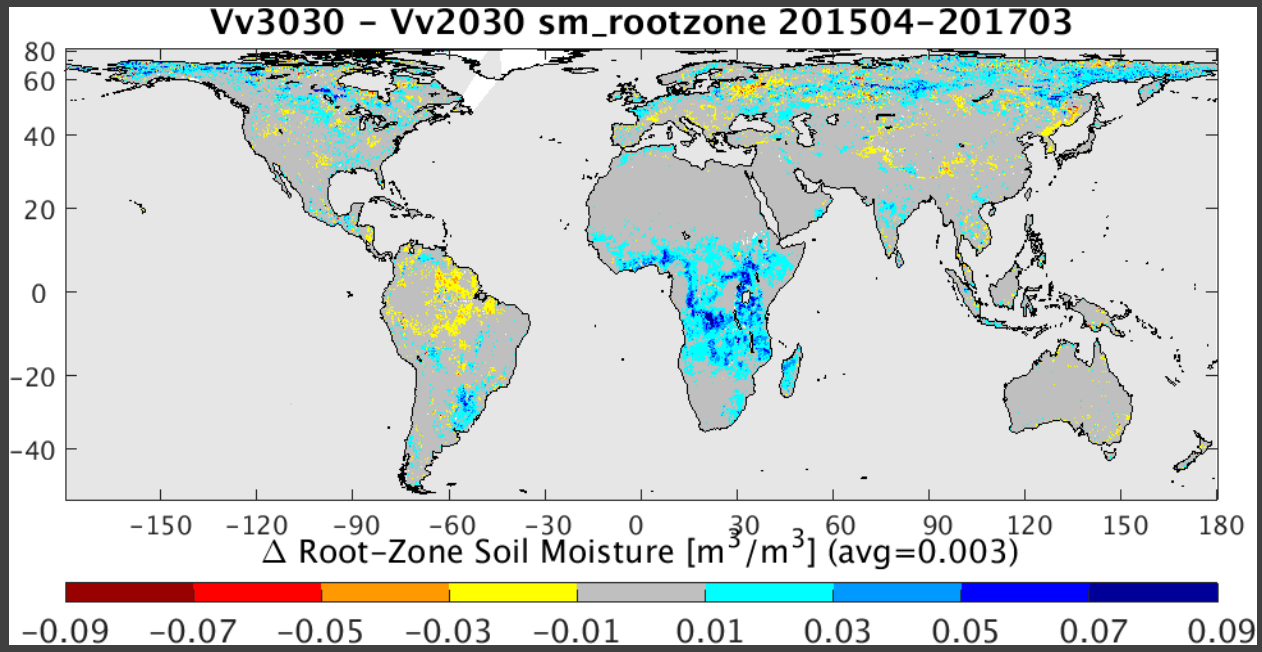
Soil Moisture Climatology

Differences in Africa are because of differences in Tb scaling parameters.

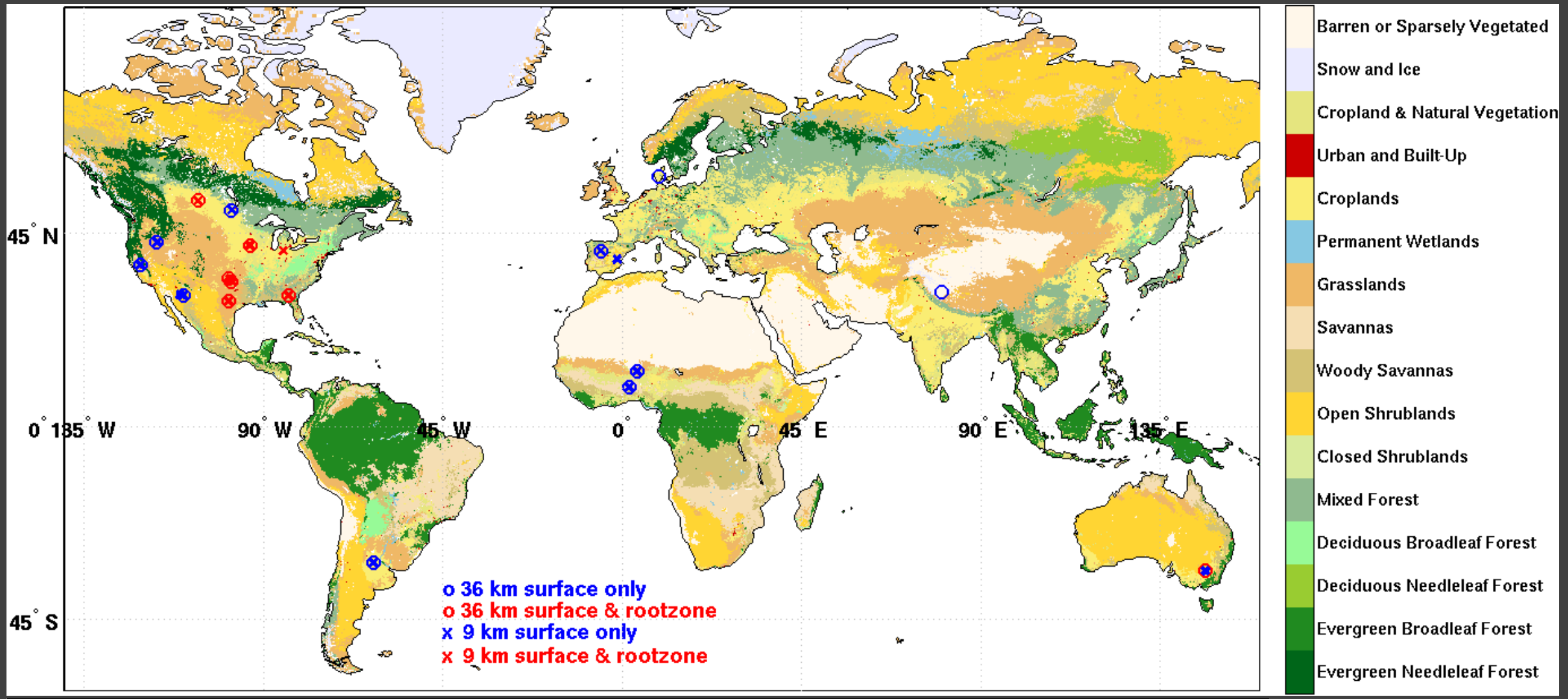
In Africa, precipitation is not corrected, and SMOS-derived scaling parameters are based on model Tbs obtained with different precipitation and other forcing inputs.

Note that in Africa, mean O-F and mean surface soil moisture increments are better in Vv3030 than in Vv2030.





Core Sites



	Surface soil moisture		Root zone soil moisture		Surface Soil Temperature (6am)		Surface Soil Temperature (6pm)	
Horizontal scale	36 km	9 km	36 km	9 km	36 km	9 km	36 km	9 km
Number of different core sites	17	17	7	6	14	12	14	13
Number of reference pixels	17	26	7	9	14	21	14	22

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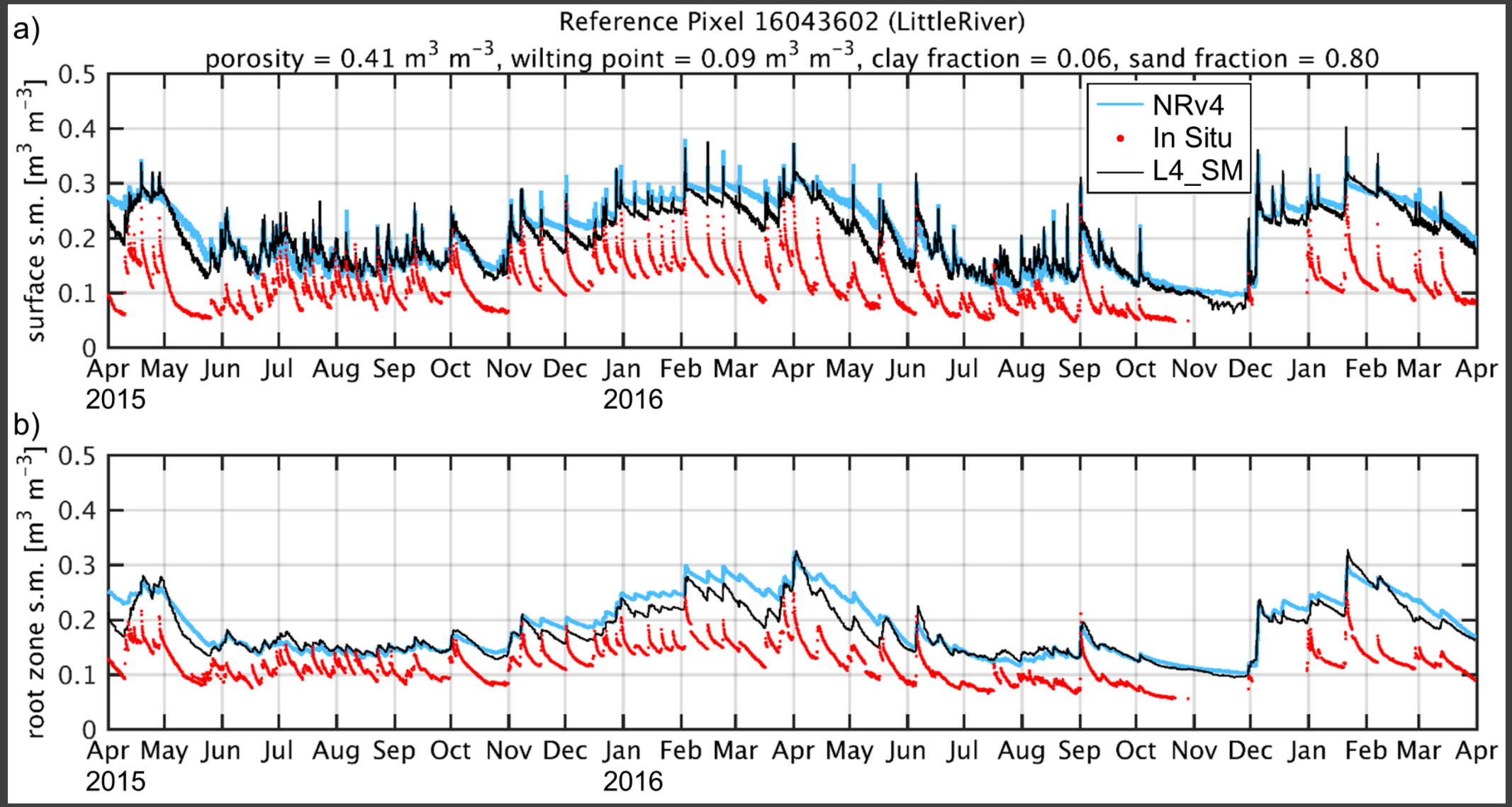
Soil Moisture at Little River (Georgia)



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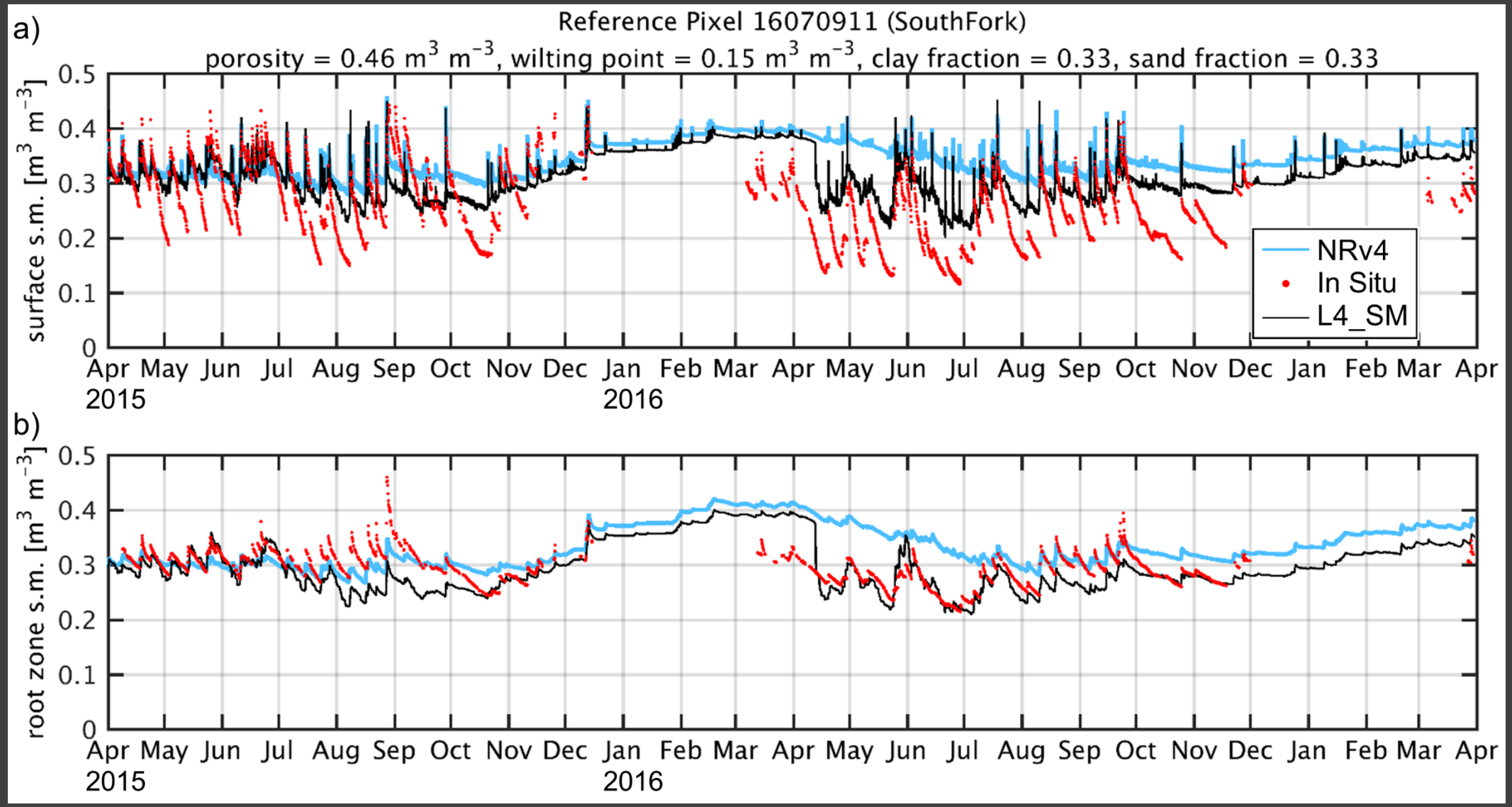
Soil Moisture at South Fork



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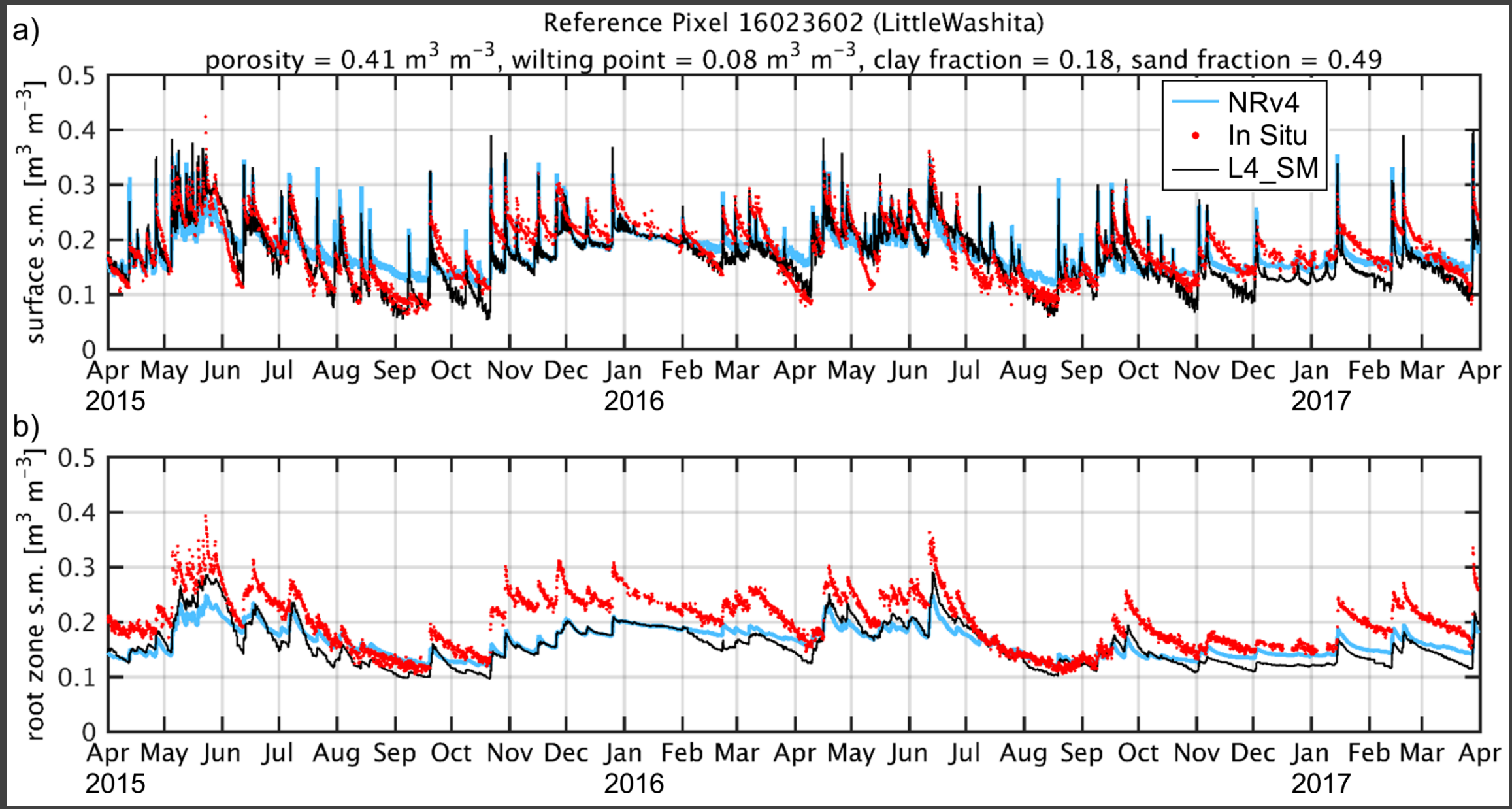
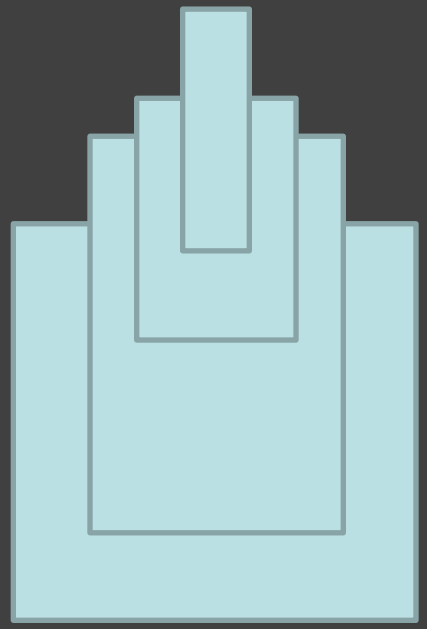
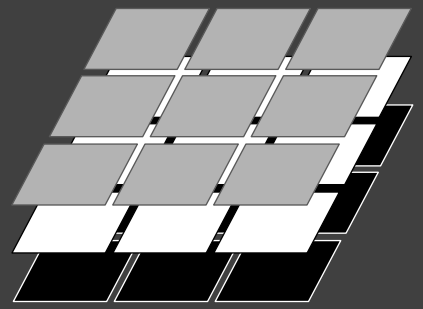
Validation vs. Core Site In Situ Measurements

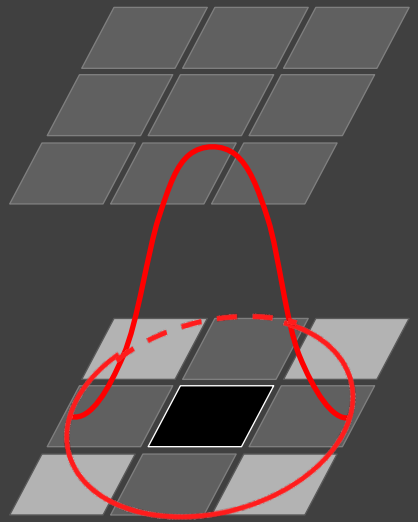


Results shown for Version 2 (Reichle et al. 2017; doi:10.1175/JHM-D-17-0063.1*). Nearly identical for Version 3.*

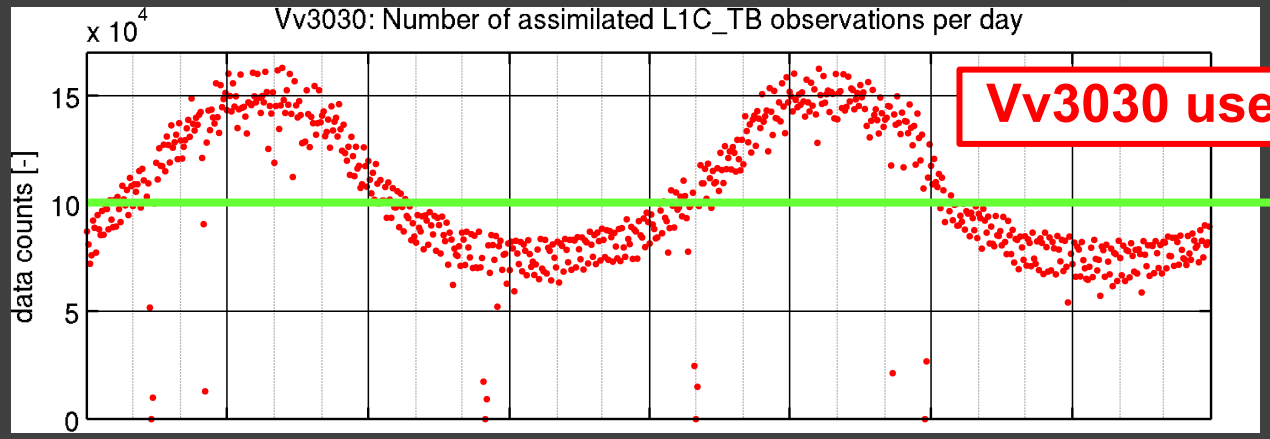
Title

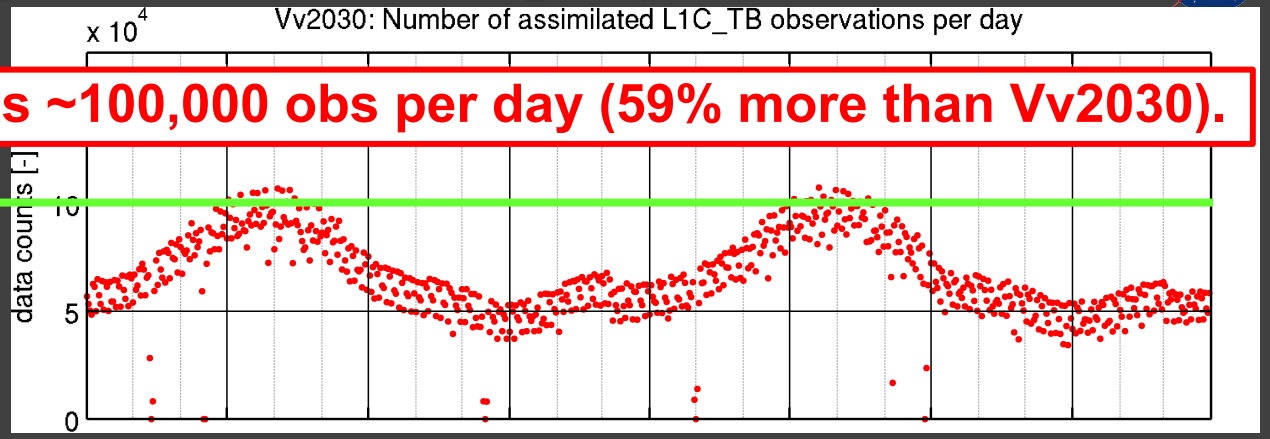




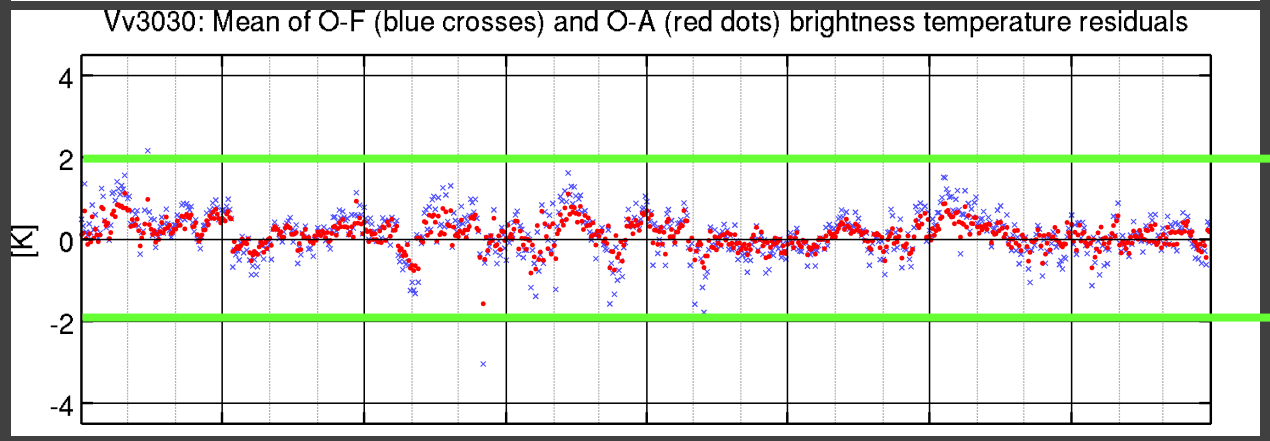


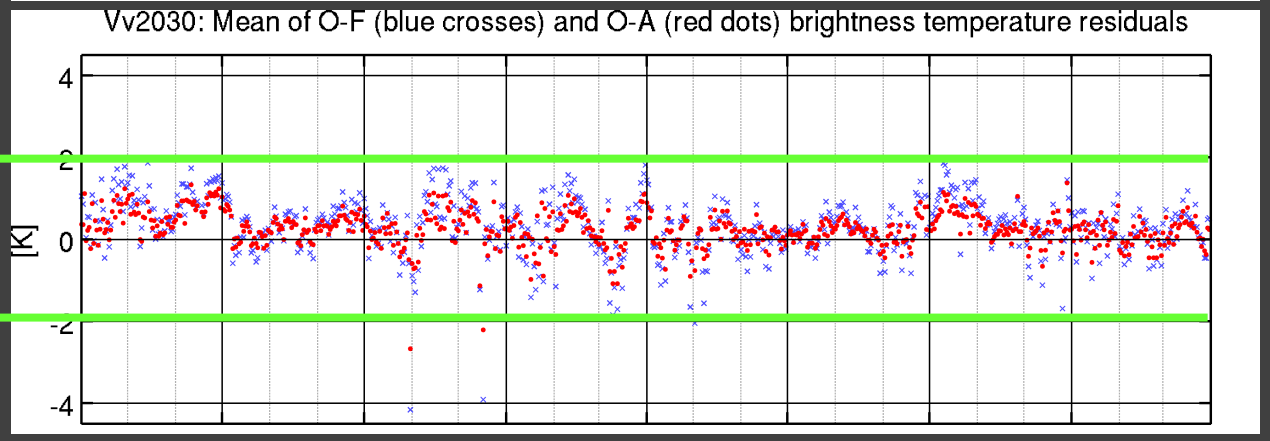
O-F Statistics (Daily Global Averages)

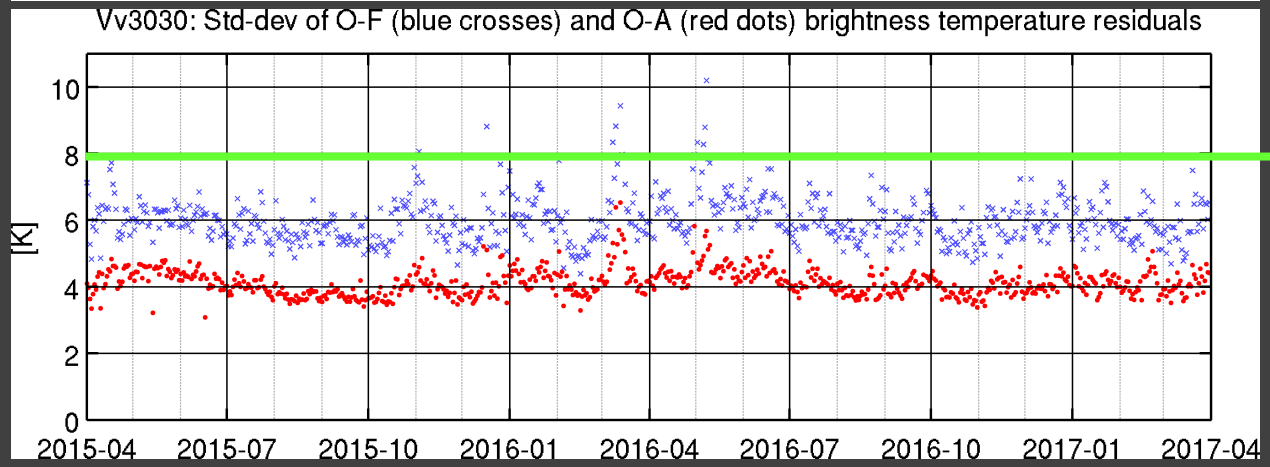


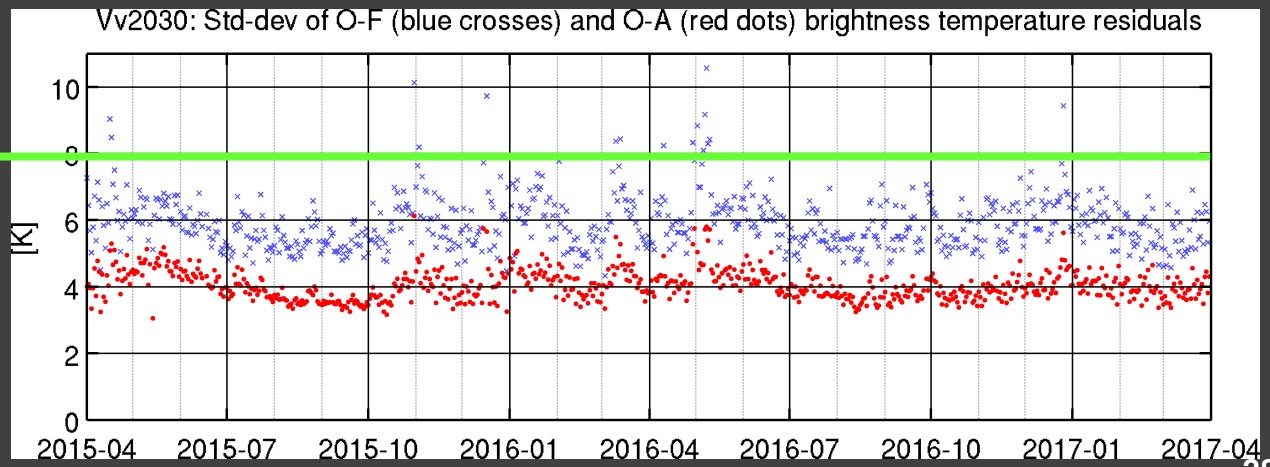


Vv3030 uses ~100,000 obs per day (59% more than Vv2030).



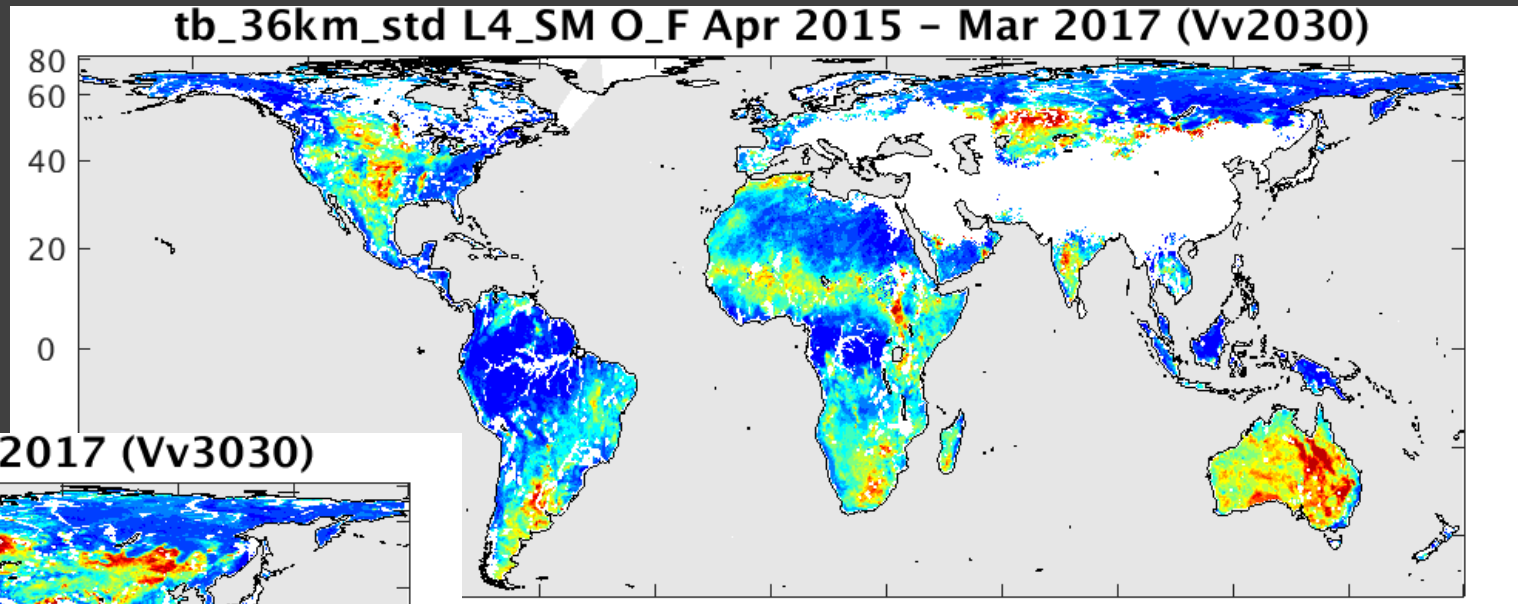


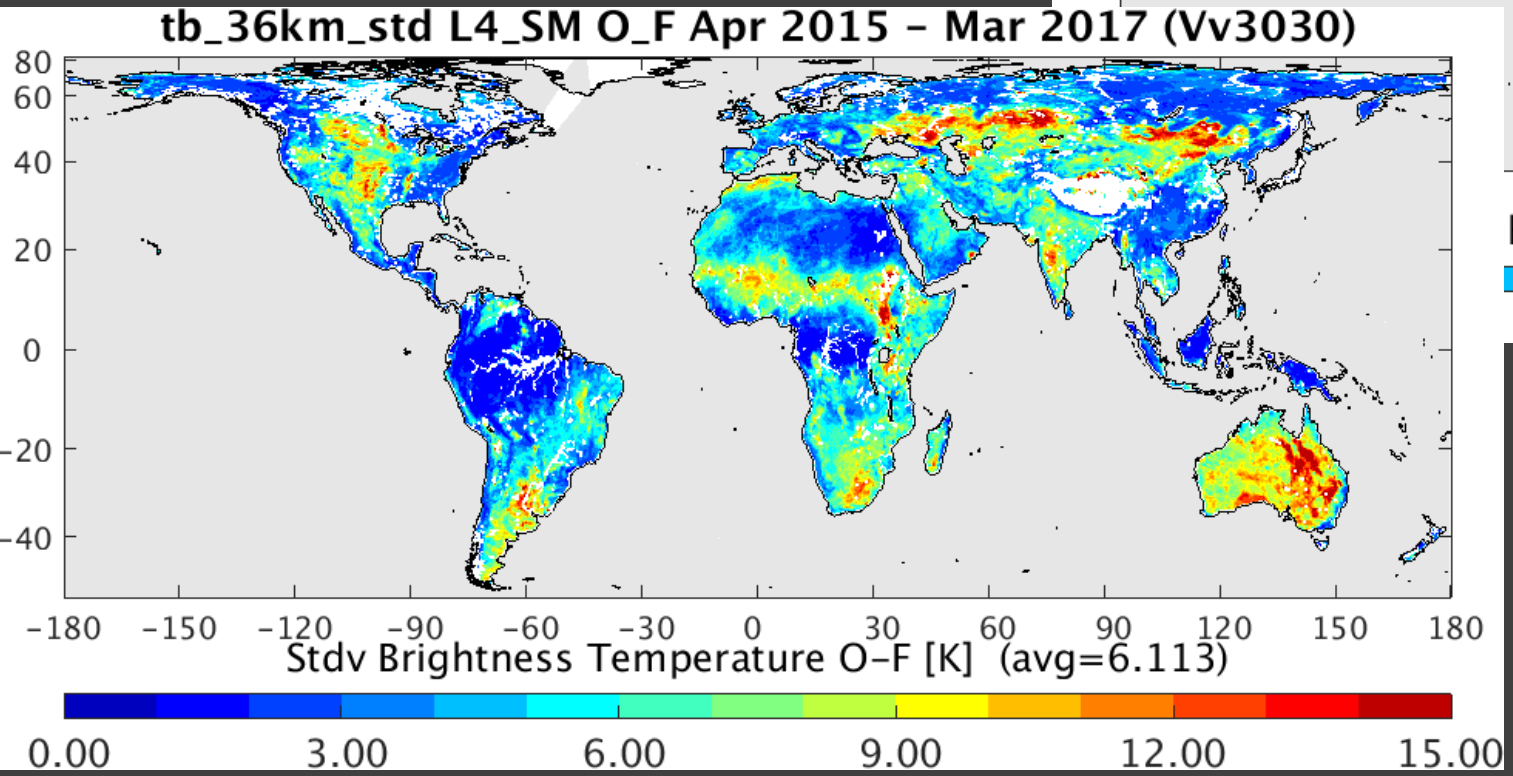




GMAO

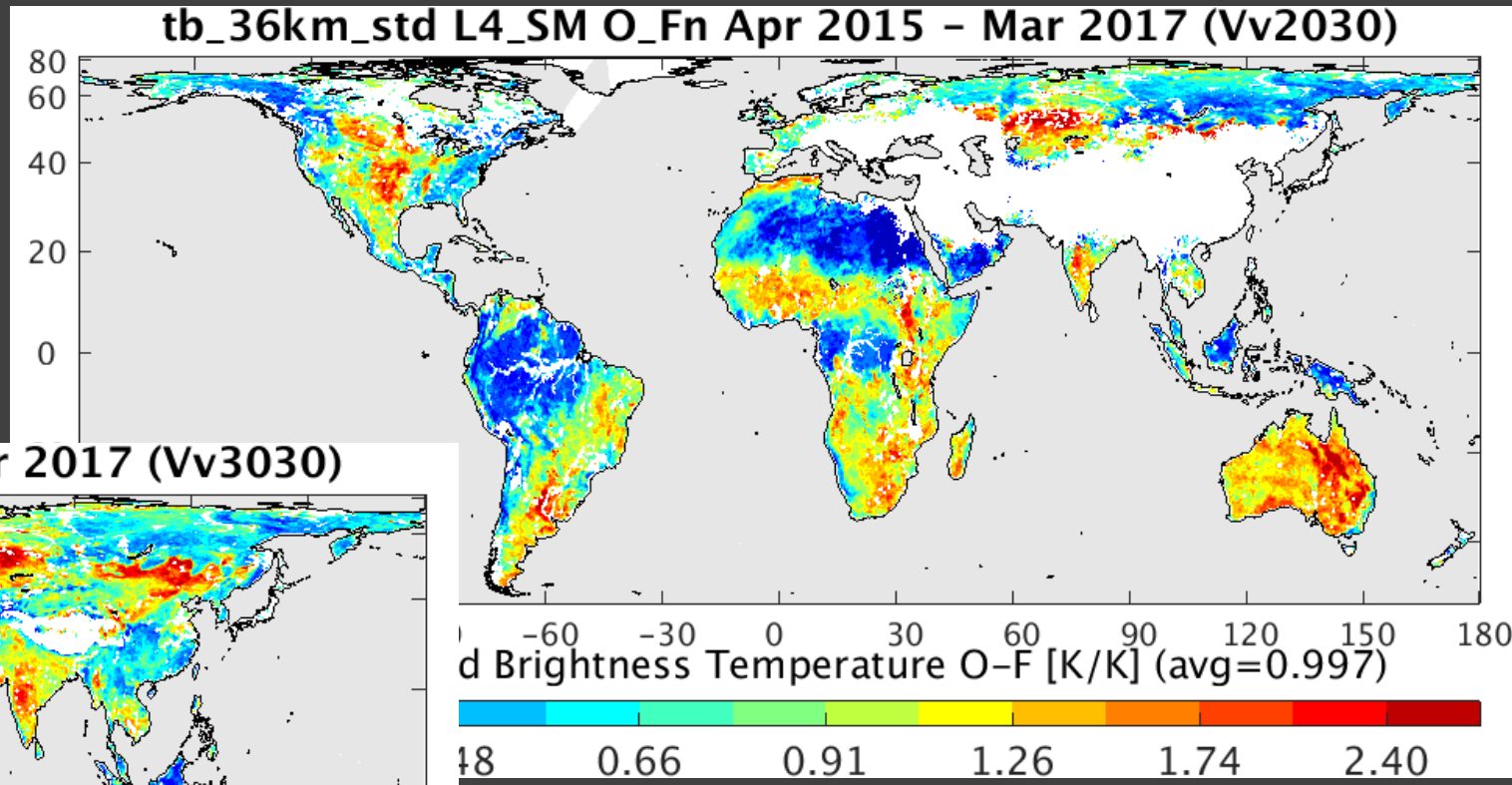
Std-dev O-F

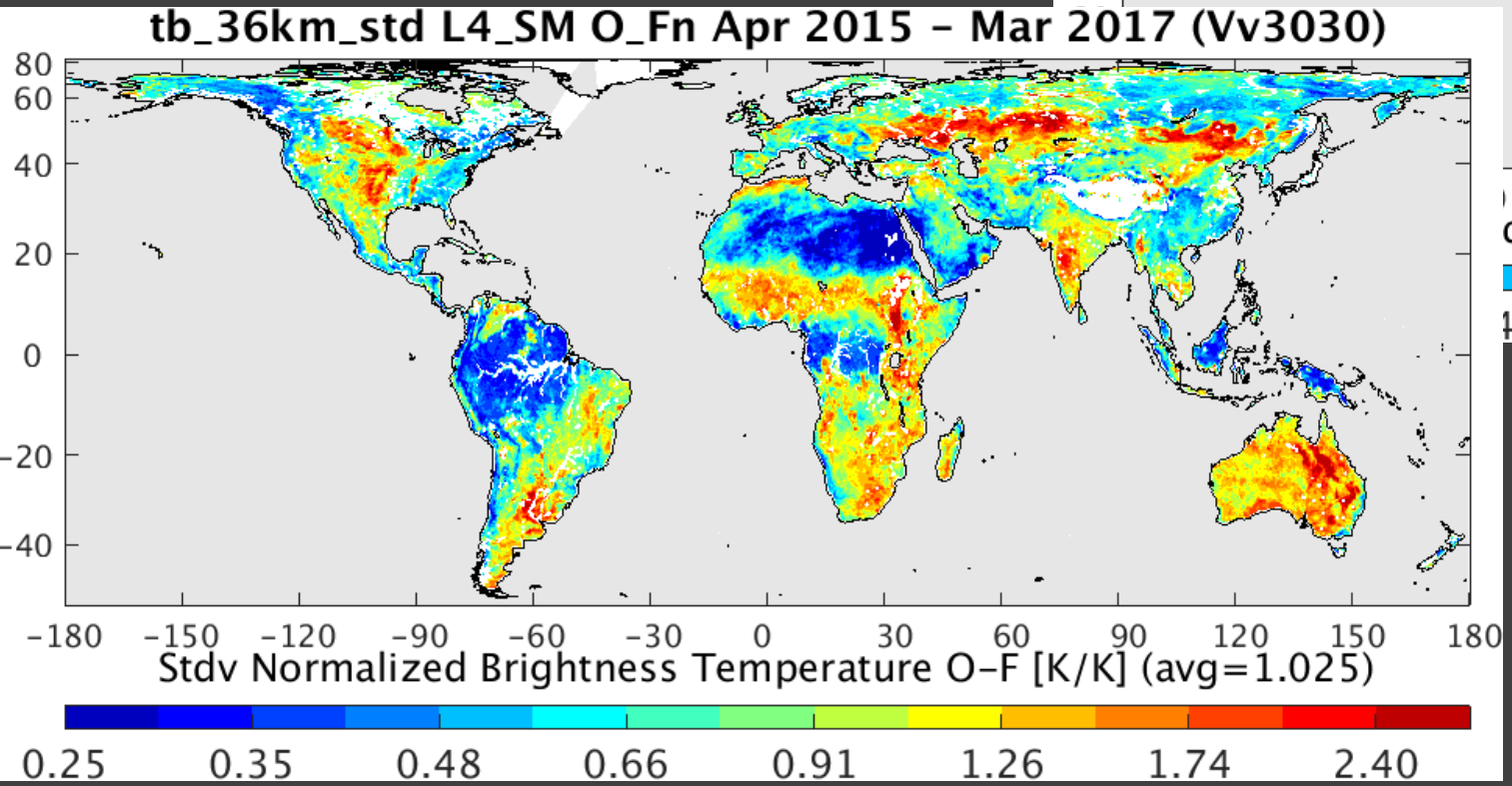




GMAO

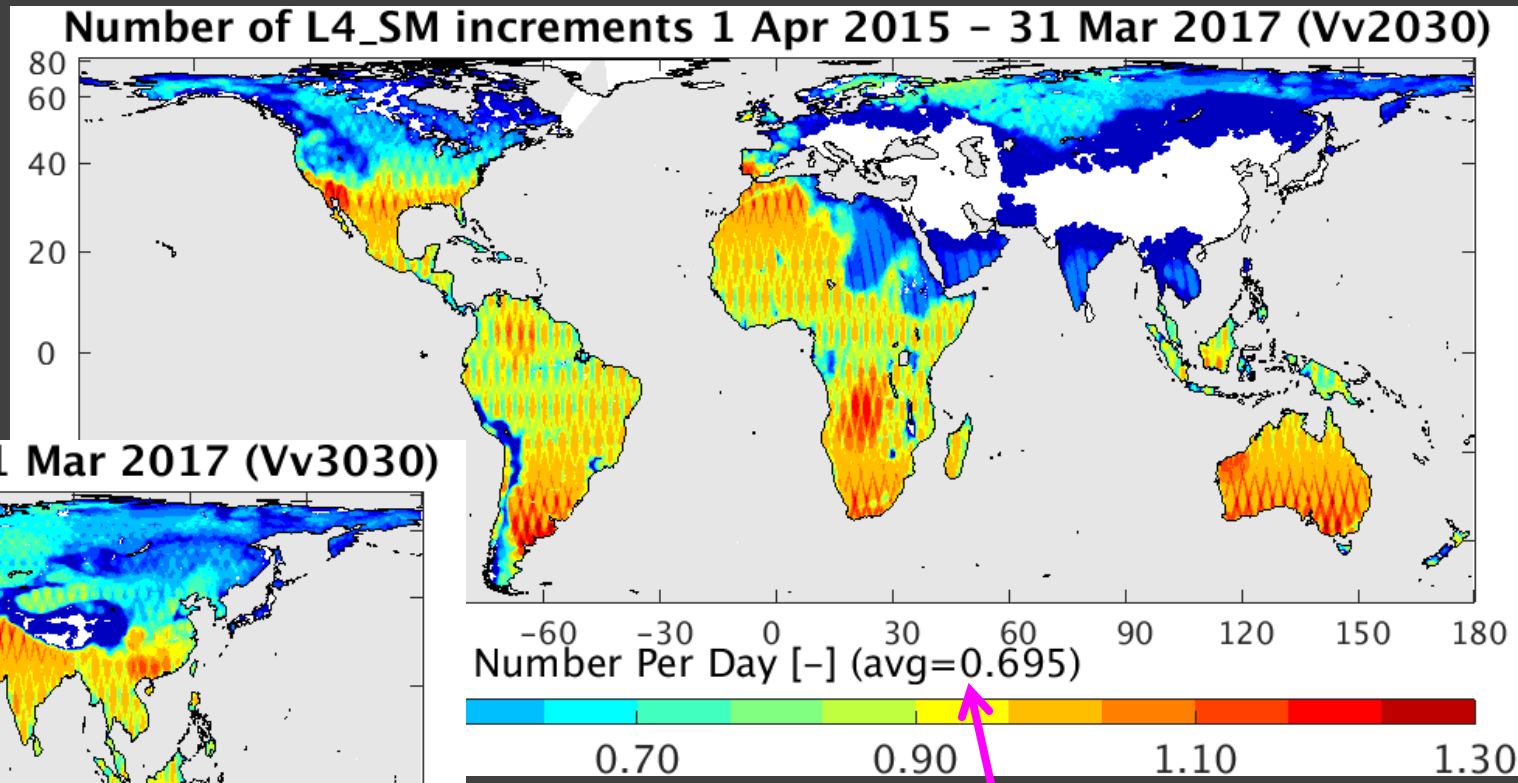
Std-dev Normalized O-F

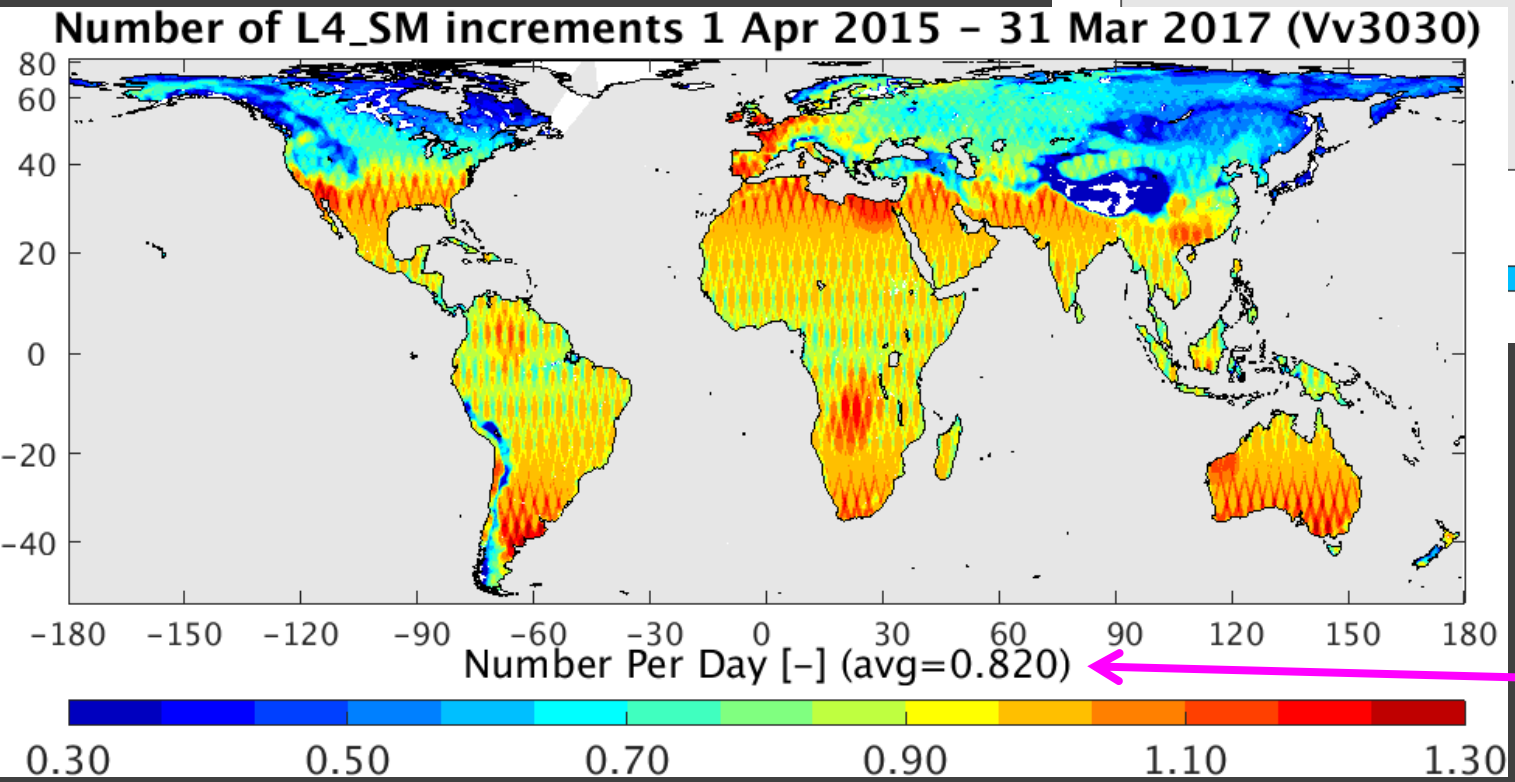




GMAO

Number of Increments

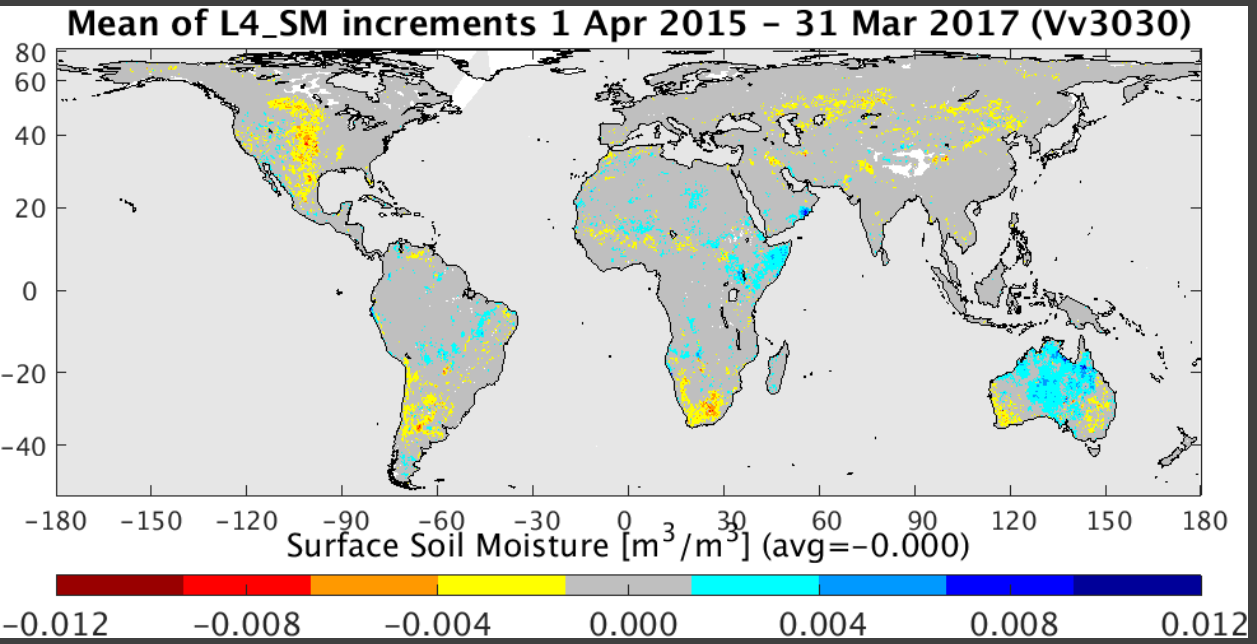


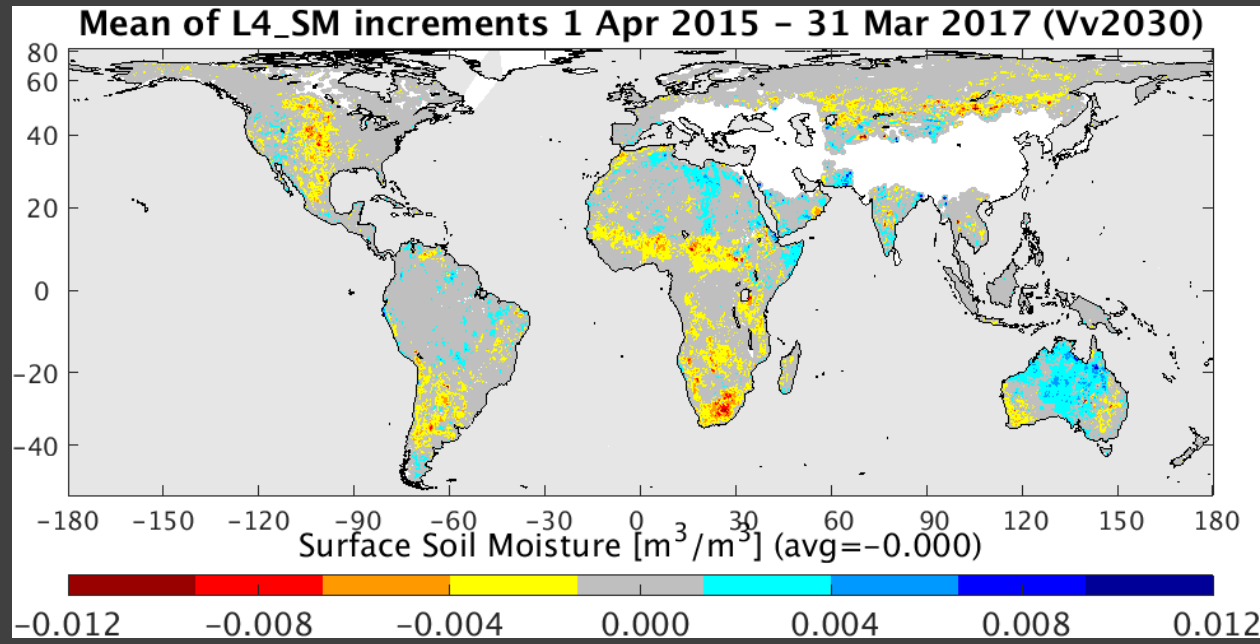


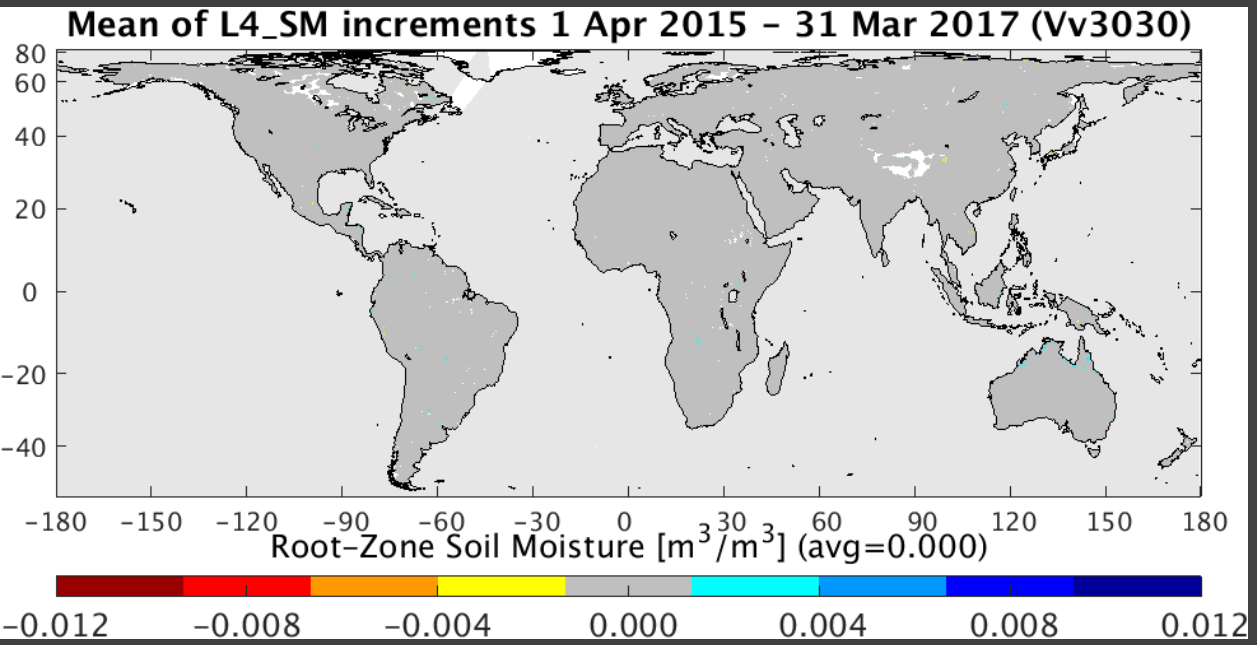
Averages exclude no-data regions

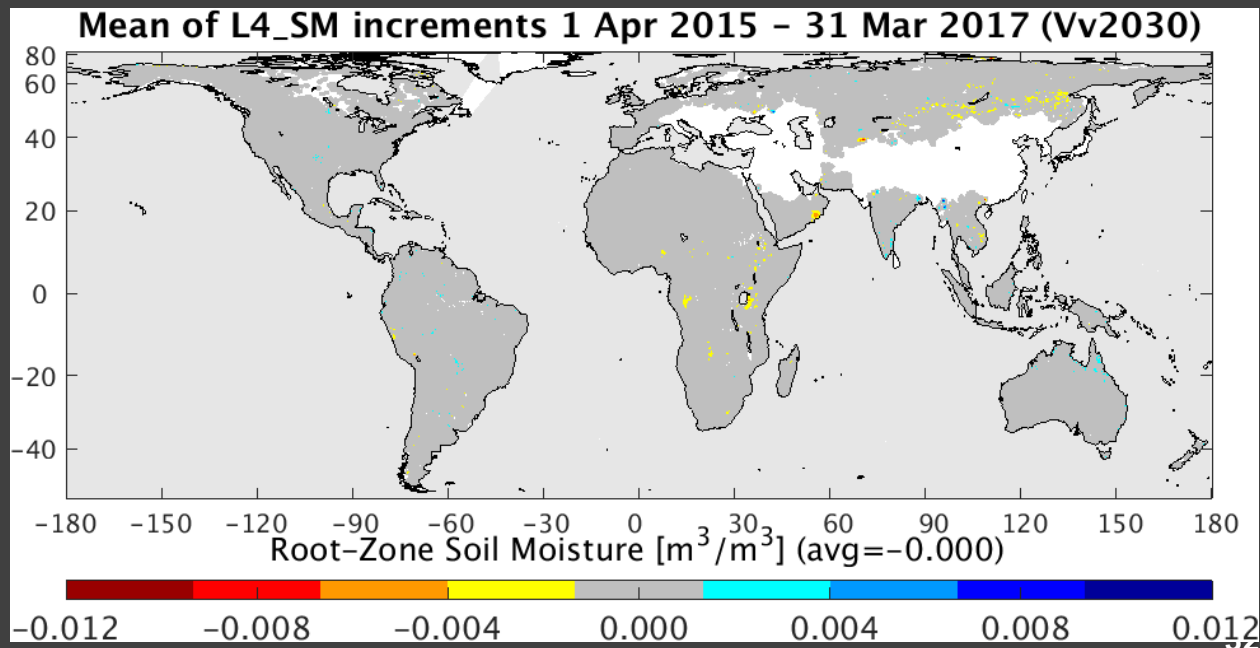
GMAO

Mean Increments



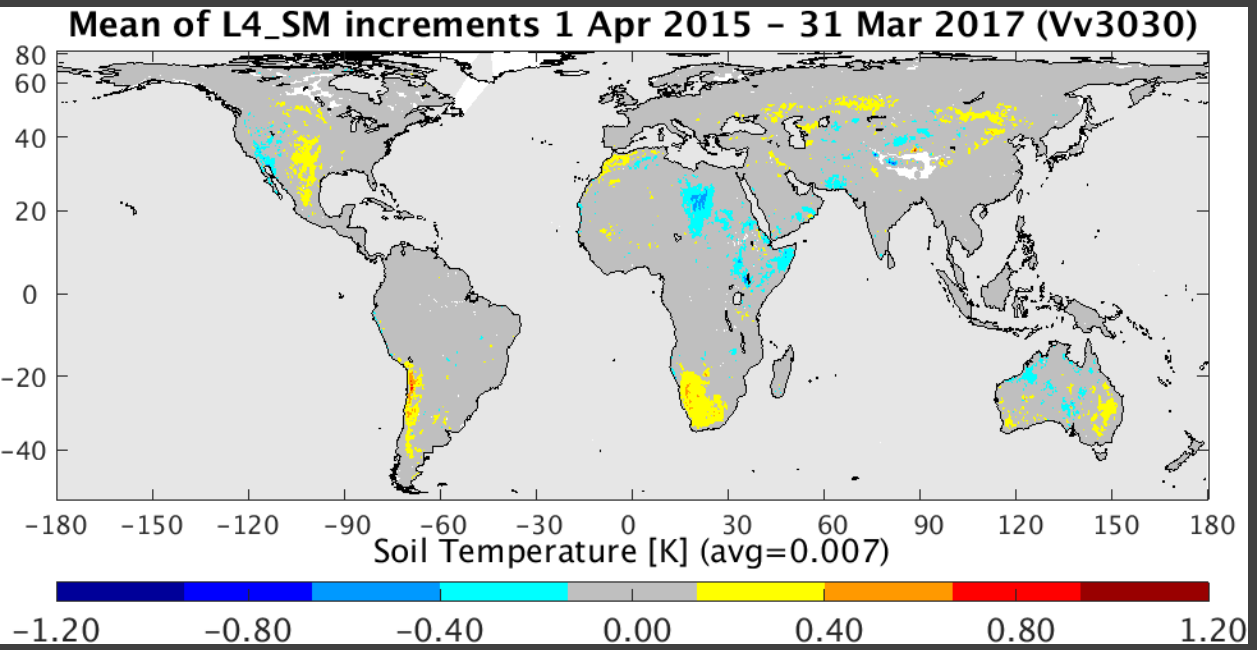


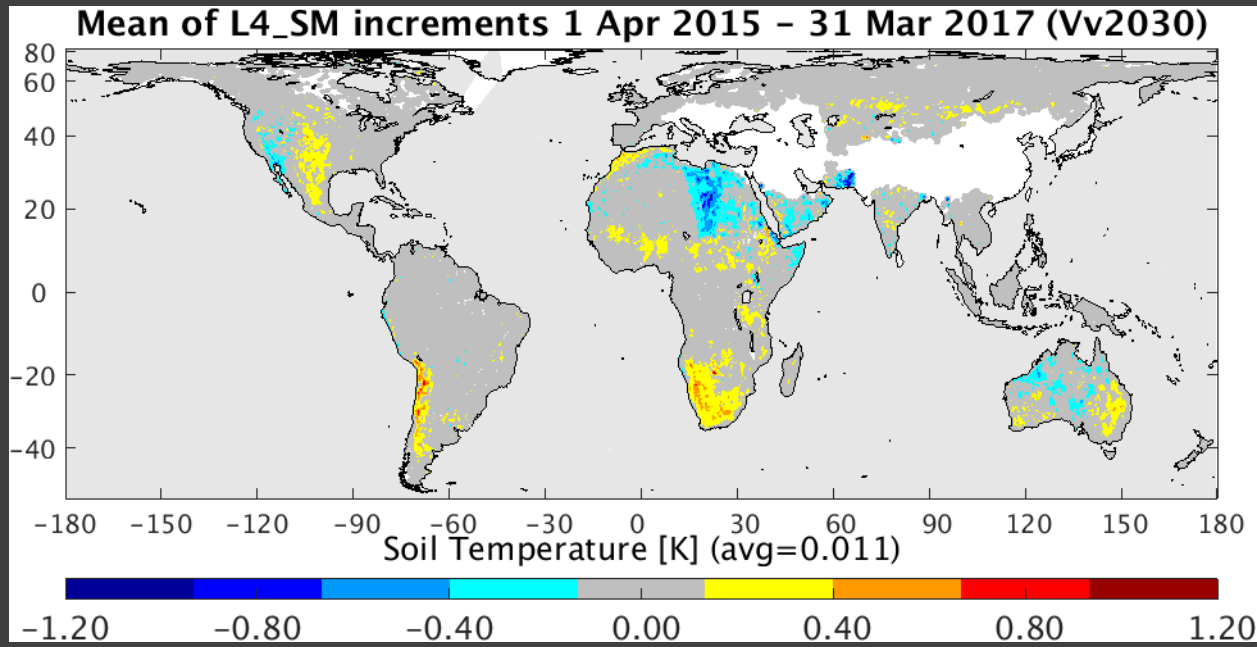




GMAO

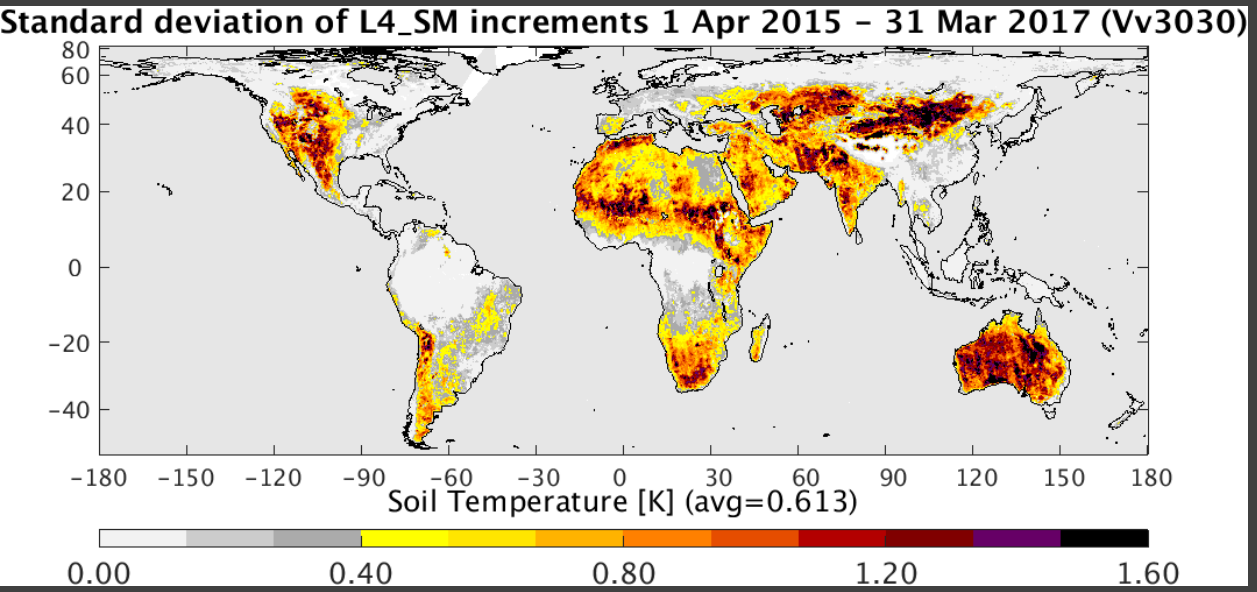
Mean Increments

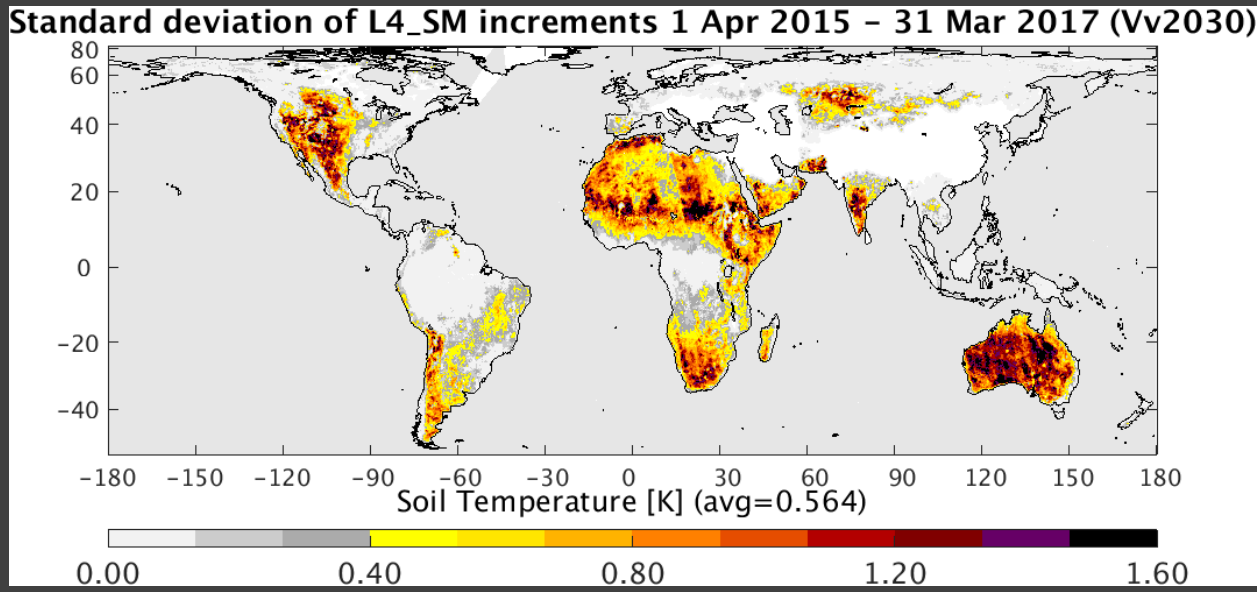




GMAO

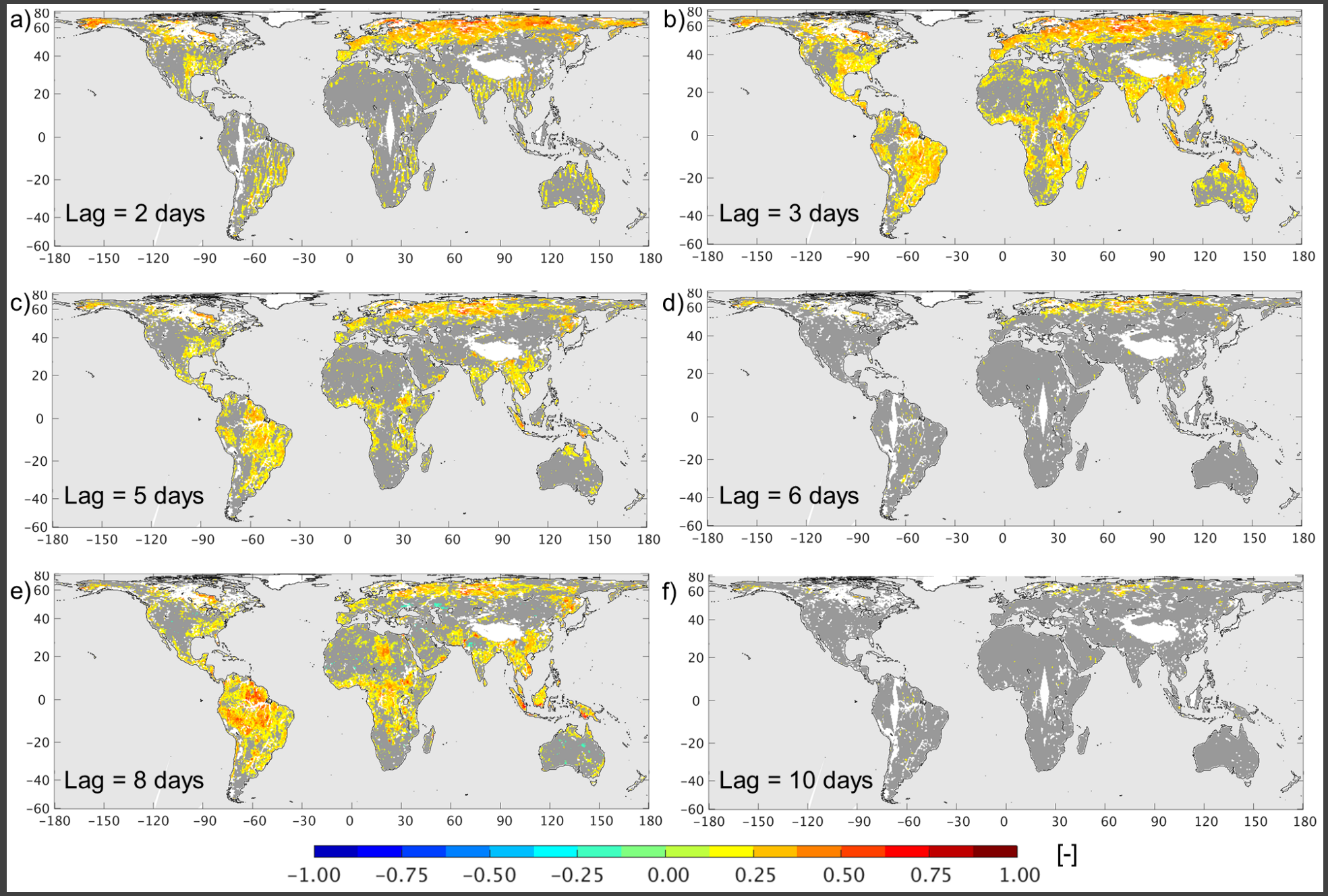
Std-dev Increments



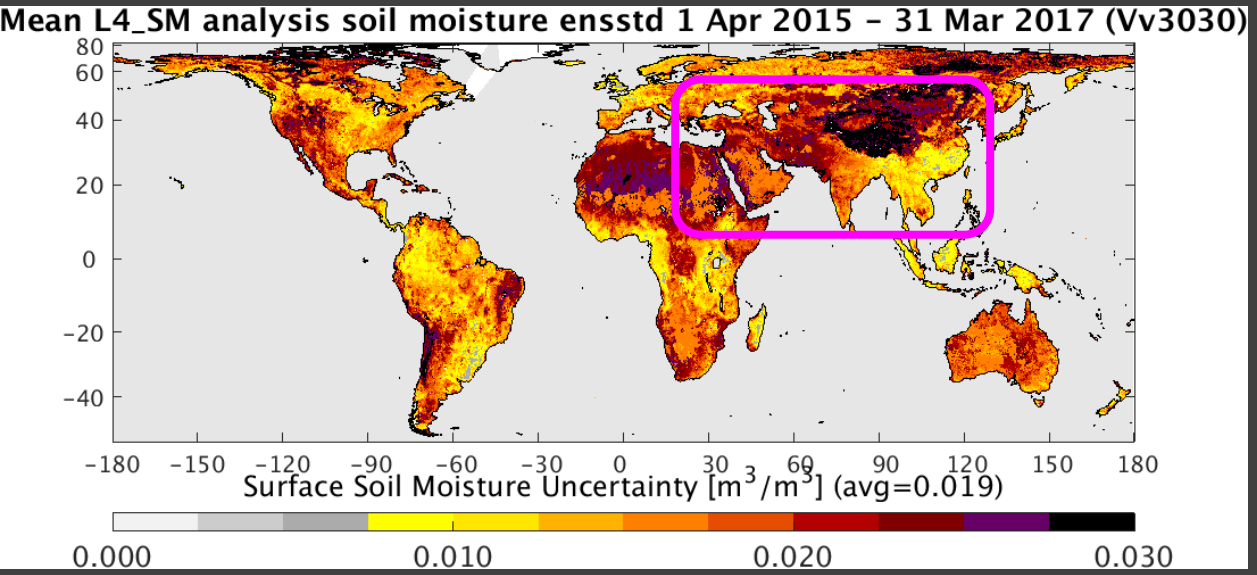


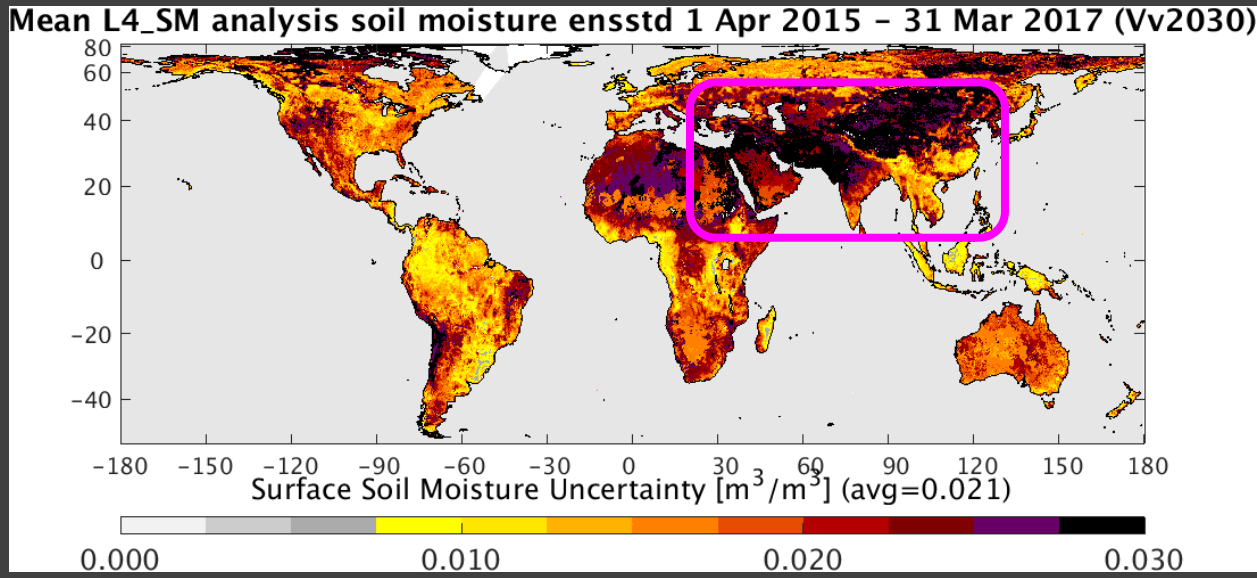
GMAO

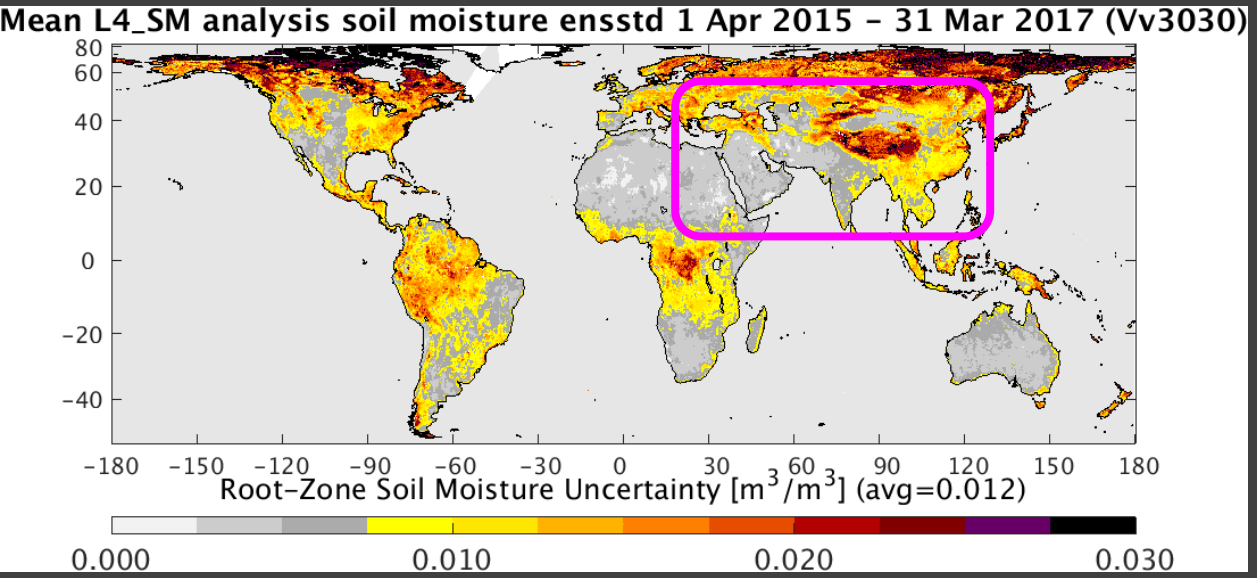
O-F Auto-correlation

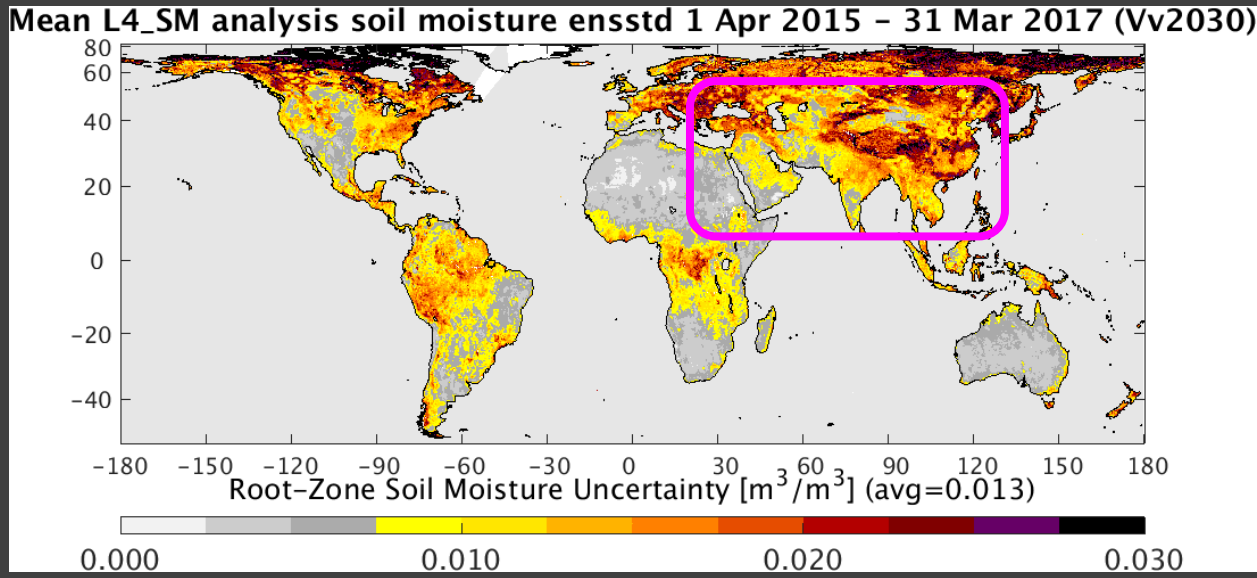


Uncertainty Estimates









Vv3030 has lower estimated uncertainty areas where Vv2030 did not use SMAP obs.

Uncertainty Estimates